Microgravity Science and Applications

Apparatus and Facilities

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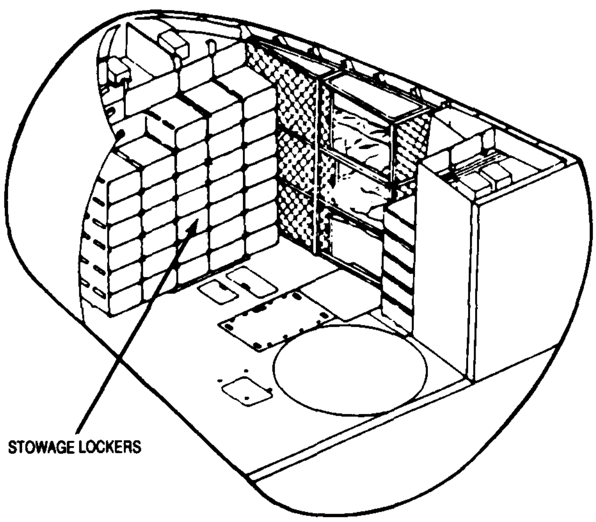
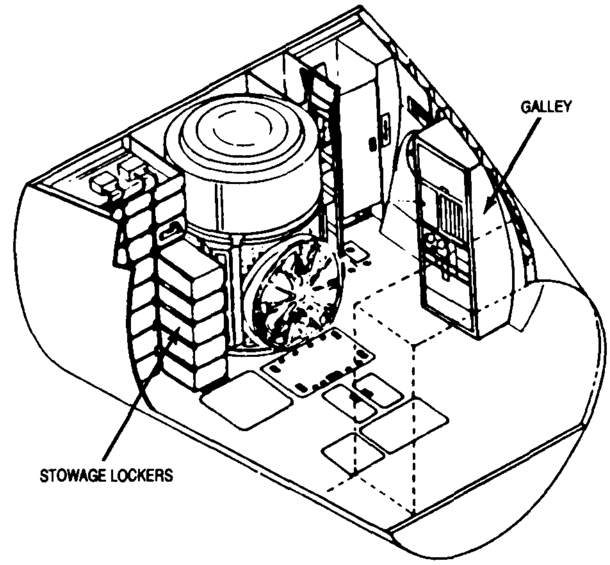
NASA

National Aeronautics and Space Administration

Orbiter Facilities



Orbiter Middeck (Forward)



Orbiter Middeck (Aft)

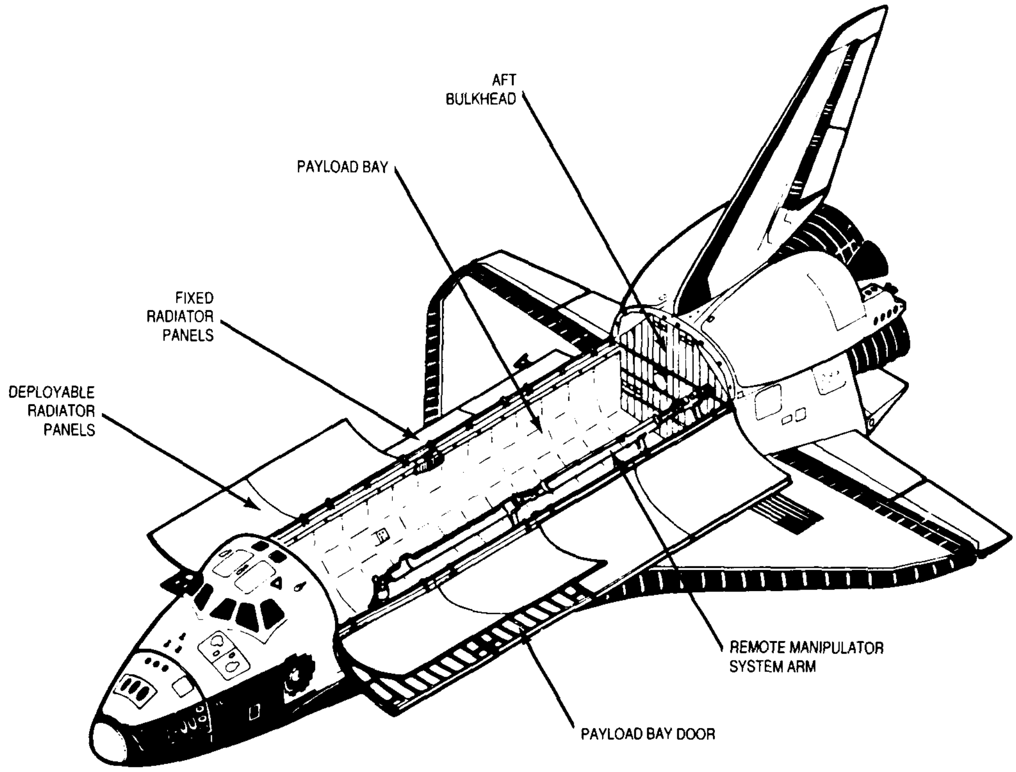
As a host facility, the orbiter provides accommodations for microgravity science experiments in two areas: the middeck and the payload bay. Several advantages and operational restrictions are unique to each area and, therefore, influence experiment design, the choice of carrier, and the means of interfacing experiment hardware to the orbiter.

Middeck

The middeck is a confined space located directly below the flight deck and adjacent to the payload bay. Resources available on the middeck are limited in both power and heat-rejection capability. The standard power available is 28 Vdc, 115 W. Although space is limited, advantages of experimentation on the middeck include:

- Potential for more frequent flight opportunities
- Reduced payload integration time and cost
- Late access to and early recovery of the experiment package
- Crew interaction with the experiment, if required.

Carriers available for use in the middeck include modular stowage lockers, Experiment Apparatus Containers (EACs), the Middeck Accommodations Rack (MAR), and the Refrigerator/Incubator Module (R/IM). The Space Acceleration Measurement System (SAMS) may also be available to investigators using middeck facilities.



Orbiter Payload Bay

Payload Bay

Greater power and heat-rejection capabilities are available to an experiment located in the payload bay than to one located in the middeck, and larger experiments can be accommodated in the more spacious bay. Integration time and cost may increase when using large carriers; however, the payload bay also has provisions for small, self-contained payloads that can be rapidly integrated on modest budgets.

With the exception of research conducted in the Spacelab carrier, all experiments in the payload bay area are activated remotely by the crew from the Aft Flight Deck or operated from the ground. The Spacelab carrier, however, offers a shirt-sleeve environment in which the crew can participate in experiments requiring real-time analysis and process modifications. These crew-interactive experiments are housed in modular units designed to fit in standard Spacelab racks.

The carriers developed for use in the payload bay are the Experiment Apparatus Container (EAC), the Get-Away-Special (GAS) Canister, the Materials Science Laboratory (MSL), and Spacelab (SL), which includes space-exposed pallets and sealed habitable modules.

Contents

Microgravity Science and Applications Apparatus and Facilities

Introduction

These Microgravity Science and Applications Apparatus and Facility fact sheets provide a summary of the physical resources available for microgravity research in space and at National Aeronautics and Space Administration (NASA) ground installations. The fact sheets describe the Space Transportation System (STS) orbiter carriers, the experiment devices that can be integrated into these facilities, and the ground-based equipment and laboratories that support space-based research.

The most sophisticated microgravity research facility is the STS orbiter. Microgravity experiments previously limited to periods of a few seconds now may be conducted for hours or days aboard the Space Shuttle.

The experiment facilities and apparatus described in these fact sheets have been designed or configured specifically for use on the orbiter and, in most cases, are flight-tested and currently available. Others are conceptual designs or prototype hardware. While mission planning, space availability, and other constraints determine the actual flight equipment configuration and carrier, various payload configurations are possible. In addition to the carriers that are currently available, concepts for new facilities for the Space Station are being developed. Flight-proven hardware is being modified to meet specific mission requirements, to increase the overall versatility of the orbiter as a microgravity research facility, and to lay the groundwork for future applications on the Space Station.

Microgravity research is a relatively new space science that demands rigorous preparation and planning. Since gravity is a dominating force on Earth, designing experiments to operate in the virtual absence of gravity is a challenge. For this reason, ground-based experimentation frequently precedes orbital research. Drop towers, drop tubes, microgravity aircraft, and dedicated laboratories simulate the orbiter's microgravity environment for periods of 2 to 30 seconds. Experiments in these facilities stimulate ideas for research and serve as test beds for microgravity experiment and equipment development.

One of NASA's objectives is to use space technology for the public benefit. To continue to develop and expand the microgravity information base, NASA encourages scientific and commercial organizations to explore the benefits of experimentation in the microgravity environment of space. These fact sheets are designed to introduce interested parties and potential users to the available microgravity research resources.

Instrumentation

Middeck stowage lockers and adapter plate interfaces provide no instrumentation; all instrumentation is provided by experiment apparatus contained in the locker tray(s) or other approved containment systems.

Data Acquisition

Modular stowage lockers have no data acquisition capabilities. Data are acquired through instrumentation provided with the experiment apparatus.

Facility Integration

Modular stowage lockers are integrated in the middeck. No structures may be attached to the locker.

- Special Interface Requirements: None
- Integration Options: None

Additional Notes

Further information about middeck accommodations is available in the Orbiter Middeck Payload Provisions Handbook (JSC-16536) and in the Orbiter Middeck Payload Standard Interface Control Document (ICD 2-1M001).

Development Center

NASA/Johnson Space Center
Customer Integration Office/TC4
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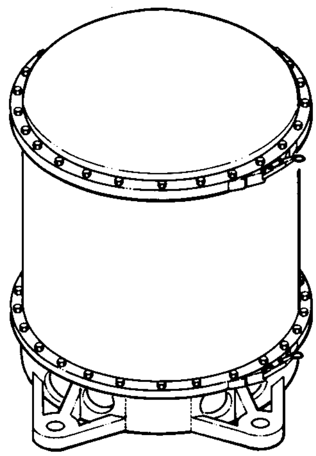
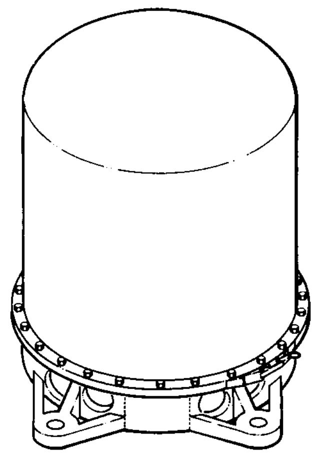
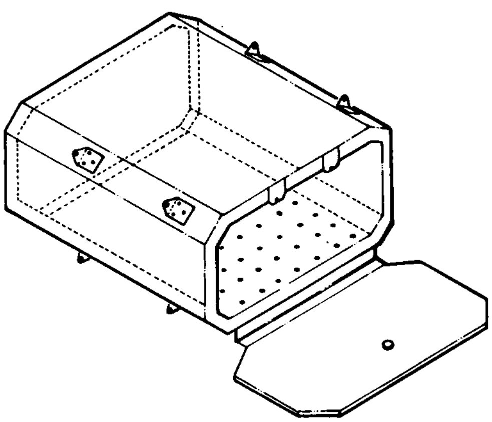
Middeck Experiment Apparatus Container (EAC)



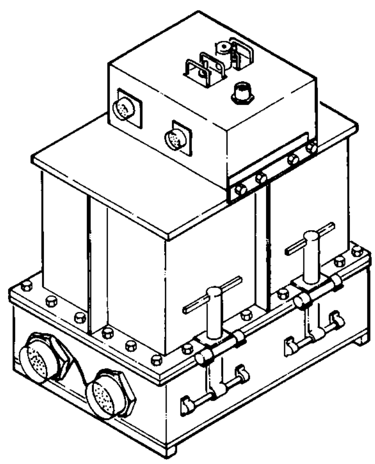
Flat Top Cylindrical EAC



Dome Top Cylindrical EAC



Rectangular Locker-Type EAC



Experiment Electronic Package

Importance

EACs are convenient, economical devices that provide protective housing for experiment apparatus. Middeck EACs may be cylindrical or rectangular and contain experiments that weigh less and have lower power requirements than EAC experiments in the payload bay. Because middeck EACs offer an enclosed and sealed environment, certain safety waivers may be granted to the materials of components enclosed in the EAC.

Method

Four kinds of middeck EACs are available. Two are removable, cylindrical housings that can accommodate a variety of experiment apparatus. These EACs have two sections: a cylindrical base on which the experiment is mounted and a taller component that encloses the experiment. One cylindrical EAC has a dome top; the other has a flat lid. A third middeck EAC is rectangular and provides a more rigid housing for experiment apparatus than either of the cylindrical containers. The fourth middeck EAC is also rectangular and provides accommodations for experiment electronics. Middeck EACs are designed for spaces normally occupied by middeck stowage lockers.

Orbiter Location

Middeck

Physical Characteristics

- Flat top cylindrical EAC
  - Container dimensions (L x dia.): 49.1 cm x 44.6 cm
  - Container weight: 12.1 kg
  - Locker spaces required: 2
  - Single adapter plates required: 2
- Dome top cylindrical EAC
  - Container dimensions (L x dia.): 81.2 cm x 44.6 cm
  - Container weight: 13.5 kg
  - Locker spaces required: 2
  - Single adapter plates required: 2
- Rectangular locker-type EAC
  - Container dimensions (LxWxH): 49.8 cm x 45.0 cm x 28.2 cm
  - Container weight: 7.6 kg
  - Locker spaces required: 1
  - Single adapter plates required: 1
- Experiment Electronic Package
  - Container base dimensions (LxWxH): 26.4 cm x 34.9 cm x 9.4 cm
  - Container middle dimensions (LxWxH): 24.1 cm x 33.0 cm x 19.0 cm
  - Container top dimensions (LxWxH): 21.3 cm x 17.5 cm x 8.9 cm
  - Locker spaces required: 1
  - Single adapter plates required: 1

Operational Parameters

- Standard power available in middeck: 28 ±4 Vdc
- Temperature: Within touch temperature; not to exceed 61 °C
- Maximum weight: 31 kg for a single locker interface; 54 kg for a double locker interface
- No access to active cooling

Instrumentation

Instrumentation is provided by the experiment apparatus.

Data Acquisition

Data acquisition capabilities are provided by the experiment apparatus.

Facility Integration

EACs are configured for installation in spaces provided for modular stowage lockers.

- Special Interface Requirements: None
- Integration Options: None

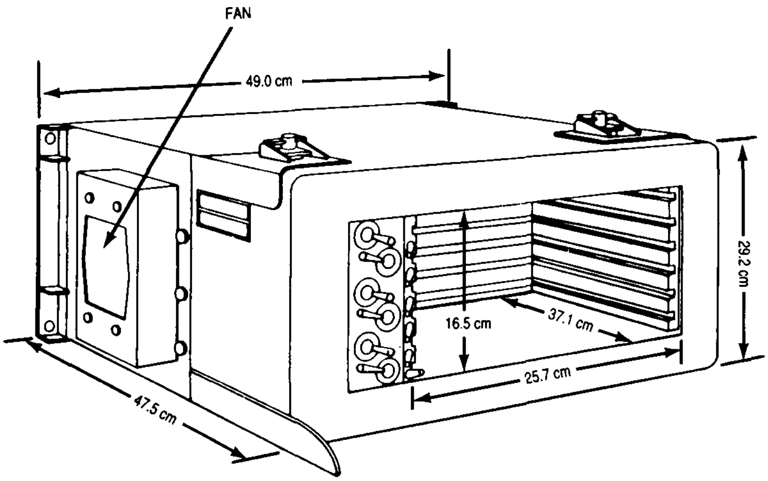
Additional Notes

Additional information on middeck EACs is available in the "Middeck Accommodations Handbook" (ST-84-MSFC-2725), January 1984, which can be obtained from the Document Repository, CN22D, Marshall Space Flight Center, AL 35812.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Refrigerator/Incubator Module (R/IM)



Refrigerator/Incubator Module

Importance

Many experiment samples, such as living cells, organisms, and materials, must be maintained at specific temperatures in preparation for or after processing. The R/IM provides an easily integrated, temperature-controlled storage area for these samples.

Method

The R/IM can provide samples with a controlled thermal environment at, above, or below ambient temperature. These samples are secured in racks in the R/IM, which can be controlled to 1-degree intervals between 4 and 37.5 °C. To cool from ambient middeck temperature (24.0 °C) to 4 °C requires 5 hours; after power to the R/IM is shut off, the rate of temperature change is 3 °C/hour until ambient temperatures are attained.

Orbiter Location

Middeck

Sample Summary

- Sample requiring stabilized temperature
- Sample volume: 0.016 m^3

Physical Characteristics

- Dimensions (LxWxH)
  - Inside: 25.7 cm x 16.5 cm x 37.1 cm
  - Outside: 49.0 cm x 29.2 cm x 47.5 cm
- Weight: 18 kg

Operational Parameters

- Power: 84 W (cyclic)
- Voltage: 24 or 28 Vdc
- Operating temperature: 4 to 37.5 °C
- Heating rate*: 1.8 °C/min
- Cooling rate*: 24.1 to 13.7 °C: 0.7 °C/min
  13.7 to 10.0 °C: 0.4 °C/min
  10.0 to 4.0 °C: 0.09 °C/min

*Data given are for 24-Vdc power; when the R/IM operates on middeck 28-Vdc power, the cooling and heating rates are increased by approximately 15%.

Instrumentation

- Switch indicating whether R/IM is operating in the cooling or heating mode
- Temperature setting

Data Acquisition

The R/IM obtains no data automatically. Crewmembers can record temperature.

Facility Integration

The R/IM replaces a standard modular stowage locker.

- Special Interface Requirements: The cooling fan of the R/IM is located on the left side of the device; therefore, the R/IM must be in a left-hand locker position to allow proper airflow through the fan. A 24-Vdc or 28-Vdc power plug is also required.
- Integration Options: The R/IM may be integrated in either the orbiter middeck or Spacelab, if a middeck locker-type interface is provided.

Additional Notes

Data contained in this fact sheet describe the R/IM used by Johnson Space Center. A modified version of that hardware with slightly broader operational parameters is used by both Ames Research Center and Marshall Space Flight Center.

Development Center

The R/IM was designed and built by McDonnell Douglas.

NASA/Johnson Space Center
SD/Medical Sciences Division
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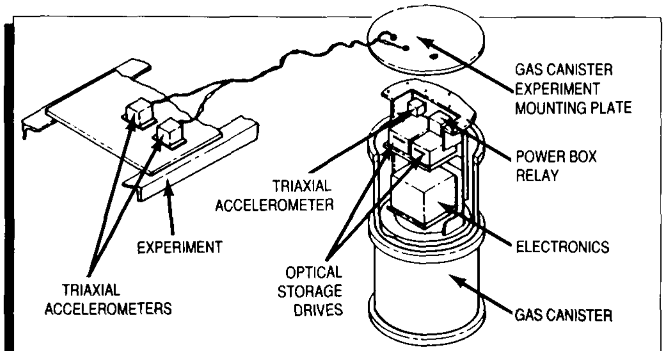
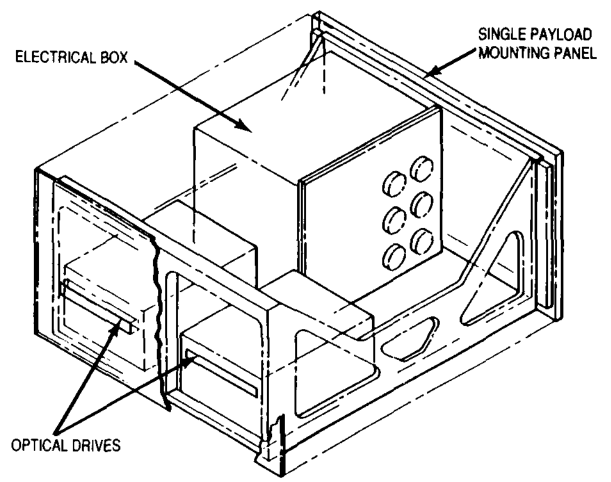
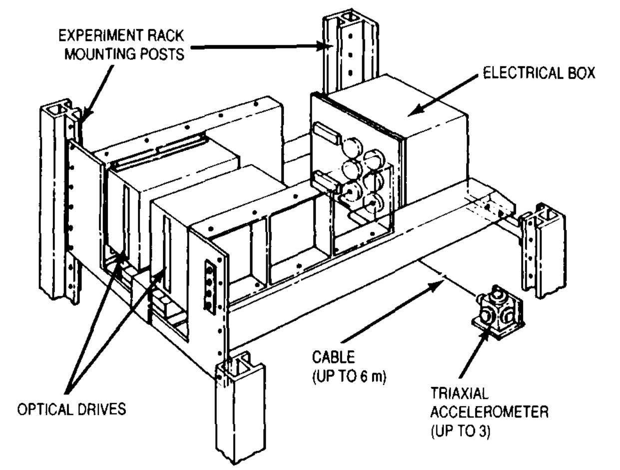
Space Acceleration Measurement System (SAMS)



SAMS GAS Canister Configuration



SAMS Middeck Configuration



SAMS Spacelab Configuration

Importance

Accelerations, which mimic the force of gravity, can greatly influence microgravity experiments that require a quiet, stable environment. The SAMS will measure, condition, and record low-g accelerations experienced by Shuttle orbiter experiments. The SAMS allows investigators to analyze data collected from experiments in light of the accelerations experienced by the experiment apparatus during space operations. The number of acceleration measurements that the SAMS can record represents a significant increase in the amount of acceleration data that will be available to experimenters. This will provide investigators with a better definition of the effects of accelerations on microgravity experimentation.

Method

The SAMS remote sensor head, a three-axis accelerometer located with an experiment apparatus and connected electrically to the main SAMS housing, sends signals to the SAMS data acquisition system in response to accelerations recorded at the site of the experiment apparatus. These signals are then amplified, filtered, converted to digital data, transferred to optical memory, and stored for postflight analysis. The SAMS data acquisition system can accommodate input from three remote triaxial accelerometers without interference.

Carrier

Orbiter middeck, Get-Away-Special (GAS) Canister, Spacelab (SL), or the Materials Science Laboratory (MSL)

Physical Characteristics

- Triaxial Sensor Head (LxWxH):
  14.0 cm x 12.3 cm x 11.4 cm
- SAMS middeck configuration (LxWxH):
  53.3 cm x 45.7 cm x 27.3 cm
- SAMS GAS configuration (LxWxH):
  70.3 cm x 45.7 cm x 33.0 cm
- SAMS SL configuration (LxWxH):
  71.8 cm x 48.0 cm x 40.6 cm
- SAMS MSL configuration (LxWxH):
  76.2 cm x 31.1 cm x 27.9 cm

Operational Parameters

- Measurement capability: Acceleration levels from ±0.5 g to 3 x 10^{-8} g (if Bell accelerometers are used)
- Voltage
  - Middeck: 28 Vdc
  - GAS Canister: 19.2- to 36-V battery
- Power profile: 65 W
- Operating temperature range
  - Triaxial sensor head and electronics package: -55 to 95 °C
  - Optical storage system: 0 to 45 °C

Instrumentation

- Triaxial sensor heads (3)
- Solid-state temperature sensors

Data Acquisition

- Simultaneous analog-to-digital (A/D) conversion of triaxial inputs, using 16-bit A/D converters
- Recording of up to 500 samples/sec from each accelerometer sensor
- Storage capability of 200 Mbytes of data per optical drive before changing the storage media (for orbiter middeck and Spacelab applications)
- Storage capability of 800 Mbytes of data when mounted in the payload bay.

Facility Integration

The SAMS is designed to support middeck, Spacelab, and payload bay experiments.

- Special Interface Requirements: None
- Integration Options: The SAMS may be integrated in the middeck, in Spacelab, on the MSL carrier, within a GAS canister, or on other payload bay carriers.

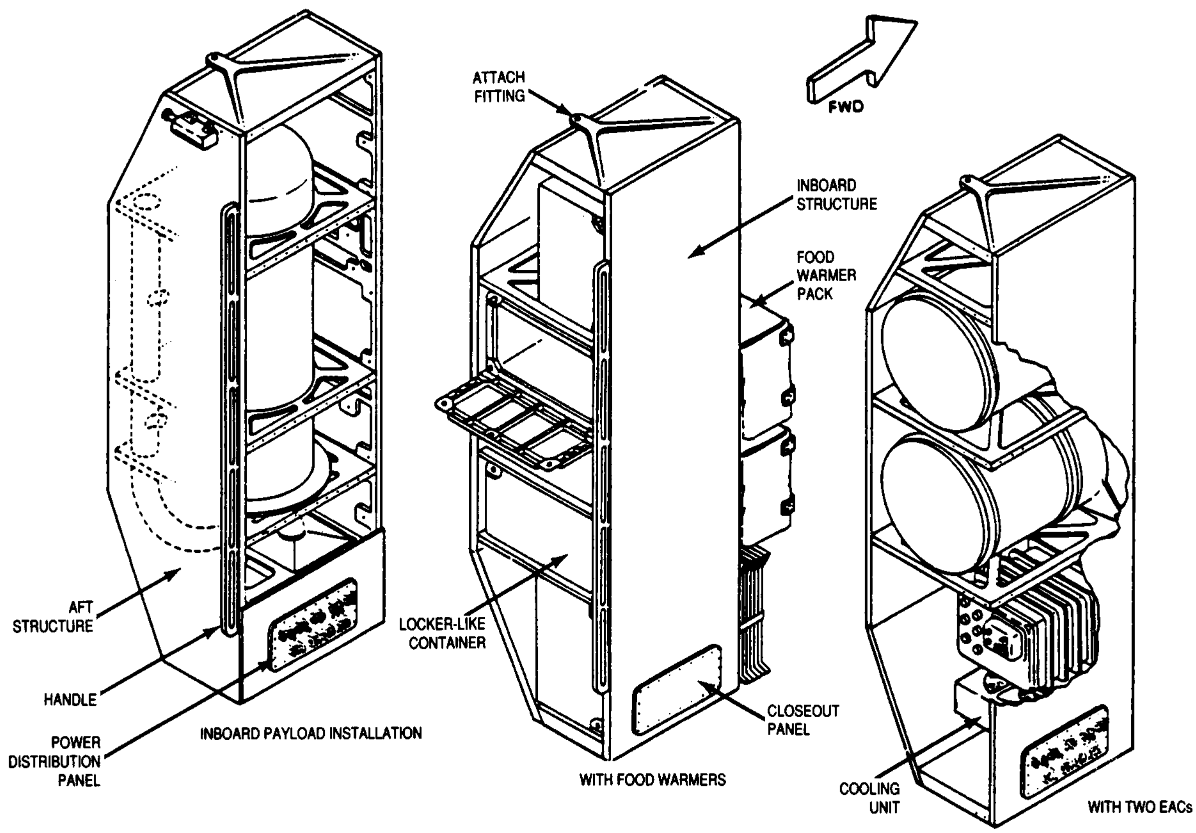
Additional Notes

The SAMS design and development were initiated in May 1986. The SAMS Critical Design Review was conducted in September 1988.

Development Center

NASA/Lewis Research Center
Space Experiments Division
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-2864

Middeck Accommodations Rack (MAR)



Middeck Accommodations Rack

Importance

The MAR will increase the space available for small payloads and experiments in the middeck by supplementing the volume occupied by middeck stowage lockers.

Method

The MAR is designed as a versatile experiment integration facility with the equivalent stowage volume of five middeck stowage lockers. Experiment Apparatus Containers, trays, combinations thereof, or payloads specially sized to the MAR's capacity can be integrated in the carrier. Power distribution and active thermal control options are available to investigators using the MAR.

Orbiter Location

Middeck

Instrumentation

- Power Distribution Panel (optional)
- Active thermal control (optional)
- Active cooling options: circulated air, cooled water for coldplates, and cooled air
- Other instrumentation required, such as experiment control and data acquisition, must be provided with the experiment apparatus.

Data Acquisition

The MAR itself has no data acquisition capabilities. Data are acquired through instrumentation provided with the experiment apparatus contained in the MAR or by other supporting instrumentation.

Operational Parameters

- Power: 28 Vdc, 115 Vac (from orbiter)
- Atmosphere: Ambient middeck
- Heat dissipation: Up to 1,000 W of experiment-generated heat (if using active thermal control option)

Physical Characteristics

- Dimensions (LxWxH): 55.88 cm x 53.34 cm x 200.66 cm
- Internal volume: 0.45 m^3
- MAR weight: 68 kg (maximum)
- Payload weight: 157.50 kg (maximum)

Facility Integration

The MAR is designed for installation at the galley attachments.

- Special Interface Requirements: None
- Integration Options: None

Additional Notes

The MAR facility is in a developmental stage. The information provided by this fact sheet describes the current facility concept.

Development Center

NASA/Johnson Space Center
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Houston, TX 77058
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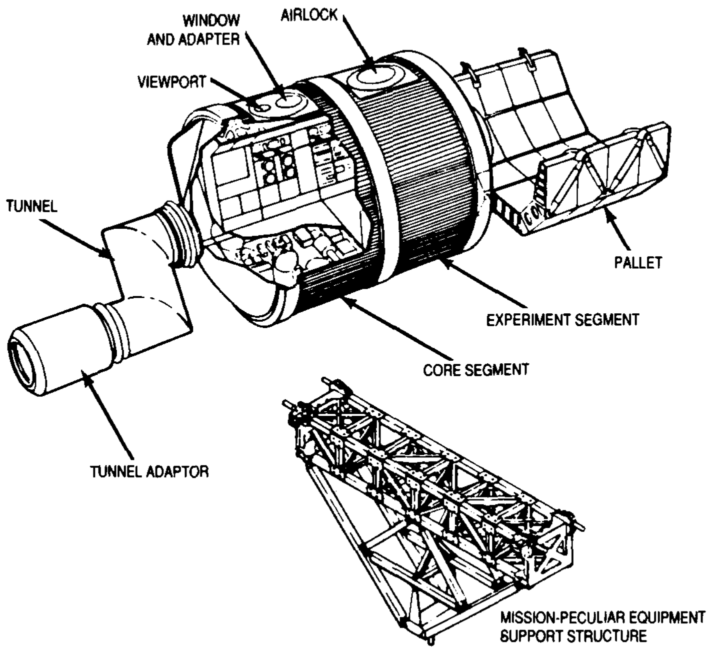
Spacelab



Spacelab

Importance

Spacelab is a versatile research center that provides a shirt-sleeve laboratory aboard the Space Shuttle orbiter as well as accommodations for instruments that require direct exposure to the space environment or no crew interaction. It can be tailored to meet the needs of multidisciplinary and dedicated discipline missions; it accommodates both large, complex facilities and smaller apparatus. Using Spacelab, investigators may interact with their experiments in several ways: by participating as Payload Specialists, scientists trained to conduct experiments in space without becoming full-time astronauts; by communicating from the ground with Payload Specialists in space; or by operating experiments by remote control from the ground. Data, specimens, and equipment are returned to investigators after flight, and experiment instruments can be retrieved and refurbished for reflight.

Method

Spacelab is a reusable, modular laboratory that fits inside the Shuttle payload bay. The two main Spacelab components are the enclosed, pressurized laboratory module and the unpressurized platforms (pallets). When pallets are flown without the module, a pressurized container (the igloo) houses the necessary subsystems support equipment. In the laboratory module, experiment apparatus can be contained in large experiment racks, overhead containers, areas beneath the floor, stowage containers, or attached to the center aisle. Also, the Spacelab Middeck Experiments (SMIDEX) concept has been developed to fly middeck-type experiments in the laboratory module, adding flight opportunities for these experiments and creating an alternative to the limited space in the orbiter middeck for experiment apparatus. For direct exposure to space, microgravity experiments may be attached directly to pallets or to the Mission-Peculiar Equipment Support Structure.

Orbiter Location

Payload Bay

Physical Characteristics

- Module
  - Short: One cylindrical core segment (4.06-m diameter, 2.70-m length); forward and aft end cones
  - Long: Two cylindrical segments (core and experiment); forward and aft end cones
- Module experiment accommodations
  - Double Rack: Volume - 1.75 m^3
    Weight - 580 kg (maximum)
  - Single Rack: Volume - 0.90 m^3
    Weight - 290 kg (maximum)
  - Center Aisle: Weight - 300 kg/m (maximum)
    Height - 1.50 m (rear of aisle); 64 cm (front of aisle)
    Width - 60 cm
  - Subfloor: Loading capacity - 300 kg/m
  - Rack-mounted Stowage Containers:
    Dimensions (LxWxH) - 49.30 cm x 39.90 cm x 28.40 cm
    Volume - 0.06 m^3
    Weight - 25 kg (maximum)
  - Overhead Stowage Containers:
    Dimensions (LxWxH) - 30.20 cm x 51.70 cm x 52.10 cm
- Pallet
  - Dimensions (LxW): 3 m x 4 m
  - Shape: U-shaped
  - Load-carrying capability: 3,110 kg (one pallet without igloo)
- Mission-Peculiar Equipment Support Structure
  - Dimensions (LxWxH): 494.79 cm x 69.93 cm x 214.96 cm
  - Shape: Truncated triangle

Operational Parameters

- Module environment
  - Pressure: 1 atm
  - Air temperature: 18 to 27 °C
  - Humidity: 30% to 70%
  - Air circulation: 5 to 12 m/min
- Power: 28 Vdc, 7 kW (peaks of 12 kW possible)
- Pallet: Directly exposed to the space environment

Instrumentation

Spacelab shares the orbiter's resources through the following systems:

- Command and Data Management Subsystem
- Data Processing Assembly
- Electrical Power Distribution System
- Environmental Control System

Data Acquisition

Data are acquired through the Command and Data Management Subsystem and can be recorded and/or transmitted directly to the ground at a rate of 48 megabits/second.

Facility Integration

Spacelab is carried in the orbiter payload bay. Crewmembers enter the Spacelab module from the middeck through the Spacelab Transfer Tunnel.

- Special Interface Requirements: Determined by the investigation
- Integration Options: Multiple Spacelab configurations are possible: module-only missions (short or long modules); pallet-only missions (up to five pallets); and module-plus-pallet(s) missions.

Additional Notes

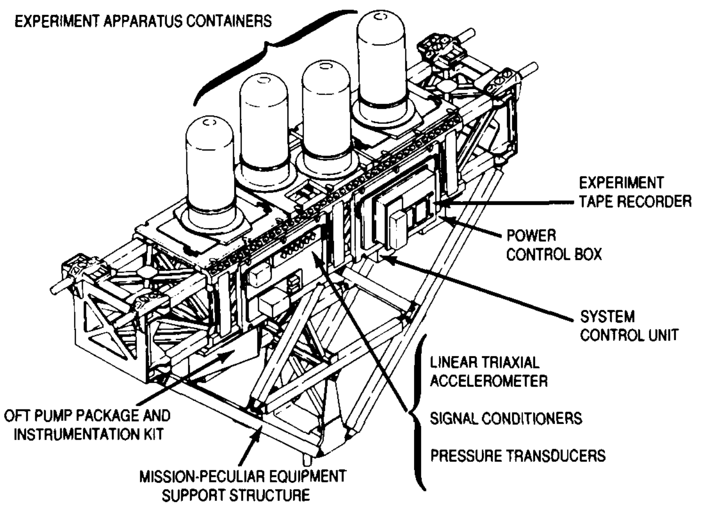
Spacelab is described in detail in the Spacelab Payload Accommodation Handbook (ESA SLP/2104), which can be obtained from the Document Repository, CN22D, Marshall Space Flight Center, AL 35812.

Development Center

Spacelab was designed by the European Space Agency for use on NASA's Space Transportation System. NASA currently maintains an inventory of Spacelab components for use aboard the Shuttle, and NASA field centers are assigned to manage specific Spacelab missions.

NASA/Marshall Space Flight Center
Mission Management Office/JA21
Marshall Space Flight Center, AL 35812
(205) 544-1927

Materials Science Laboratory (MSL)



Materials Science Laboratory (MSL-2 Payload)

Importance

The MSL carrier accommodates a variety of microgravity science apparatus and is especially adapted for large, heavy payloads. The MSL carrier provides structural support, power, environmental control, and command and data handling, reducing the complexity of designing an experiment for a Shuttle flight. The difficulties in experiment preparation and integration are minimized by MSL use: cost is reduced, the time of equipment tieup between flights is shortened, and the MSL can be prepared quickly for the next flight.

Method

The MSL carrier provides power, experiment control, heat rejection, low-g accelerometers, and data recording to a maximum of three experiment apparatus. Designated experiment equipment and subsystems mounted on a base structure called the Mission-Peculiar Equipment Support Structure (MPESS) form a specific MSL configuration. An experiment may be operated by crewmembers using a control panel in the Shuttle Aft Flight Deck, by the investigator who can uplink commands from the ground, or by automatic programmed commands. Between missions, the MPESS and subsystems remain integrated and ready for flight, and the experiment hardware is returned to the experiment developer.

Orbiter Location

Payload Bay

Physical Characteristics

- Required area: One-fourth of the Shuttle payload bay
- Mounting area: Each experiment is typically allocated one top and one side area.
  - Top area: 85.4 cm x 101.6 cm
  - Side area: 73.9 cm x 101.6 cm
- Weight: 925.3 kg for all experiments; 308.4 kg per experiment, if three are flown
- Housing: Optional Experiment Apparatus Containers can be provided as protective housing for up to 125 kg of experiment hardware.

Operational Parameters

- Power: 2,595 W (peak), 1,410 W (continuous) for all MSL payloads; 865 W (peak), 470 W (continuous) for each experiment when 3 are flown
- Energy: 32.1 kWh for each of 3 experiments
- Voltage: 28 ±4 Vdc
- Data handling: 16 kbps

Instrumentation

- Environmental Control Subsystem
- Electrical Power Subsystem
- Command and Data Management Subsystem

Data Acquisition

Instrument health status and experiment data are acquired through the System Control Unit and recorded by the Experiment Tape Recorder for postflight analysis and/or downlinked to the ground for real-time analysis. The accelerometer provides low-amplitude acceleration measurement data that are recorded by the System Control Unit and downlinked during the mission.

Facility Integration

The MSL carrier can be inserted in more than 30 locations in the Shuttle payload bay.

- Special Interface Requirements: The experiment developer must provide cables and bolts for connection to the MSL carrier subsystems.
- Integration Options: An experiment may be attached to the MSL carrier by three methods: mounted directly to the MPESS rails; mounted to an experiment-provided baseplate that spans the space between the rails; mounted to a NASA-provided or experiment-provided coldplate support structure and coldplate. Experiment Apparatus Containers are available as experiment housing, but investigators may also provide their own housing.

Additional Notes

The MSL carrier is described in more detail in the Materials Science Laboratory (MSL) Users' Handbook (Document No. HB-SI-09-84-1100, November 1985) and the Materials Science Laboratory Users' Handbook Executive Summary (Document No. HB-SI-09-84-1100, February 1986). Both handbooks may be obtained from the Document Repository, CN22D, Marshall Space Flight Center, AL 35812.

Development Center

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Mission Management Office/JA21
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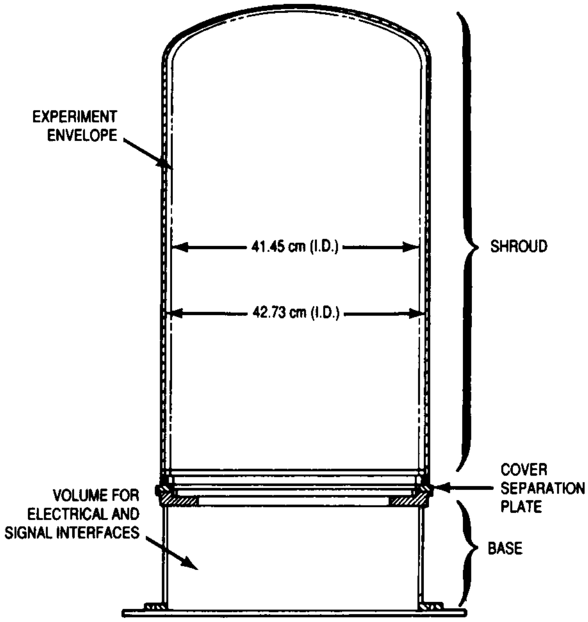
Payload Bay Experiment Apparatus Container (EAC)



Payload Bay Experiment Apparatus Container

Importance

EACs are convenient, economical housings or covers for experiment apparatus and are easily integrated onto the Materials Science Laboratory (MSL). The payload bay EAC houses experiment apparatus with greater weight and power requirements than can be accommodated by the middeck EACs.

Method

The EAC is a removable, bell-shaped containment shroud that can house a variety of experiment apparatus. The EAC has two sections: a tall shroud that encloses the experiment and a base ring section where the experiment attaches to the EAC. The payload bay EAC is mounted on the MSL carrier and uses the carrier's host subsystems for control and support.

Orbiter Location

Payload Bay

*Physical Characteristics**

- EAC only
  - Inner diameter: 42.73 cm
  - Weight: 33.75 kg
  - Inner height: 99.06 cm
- Apparatus constraints
  - Maximum volume: 0.15 m^3
  - Maximum diameter: 41.45 cm
  - Minimum top clearance: 0.64 cm
  - Operating pressure: 1 to 1.4 atm
  - Maximum weight: 123.75 kg (maximum)

*Data describe a standard payload bay EAC; various fixed inner heights (up to 143.5 cm) are available with modified EACs.

Operational Parameters

The experiment inside the EAC is commanded on or off by the orbiter crew.

Instrumentation

No instrumentation is provided by the payload bay EAC; it uses the MSL electrical and signal equipment. Feedthroughs for electrical power, signal, and fluid interfaces are located in the lower part of the EAC.

Data Acquisition

No active data system elements are provided by the EAC.

Facility Integration

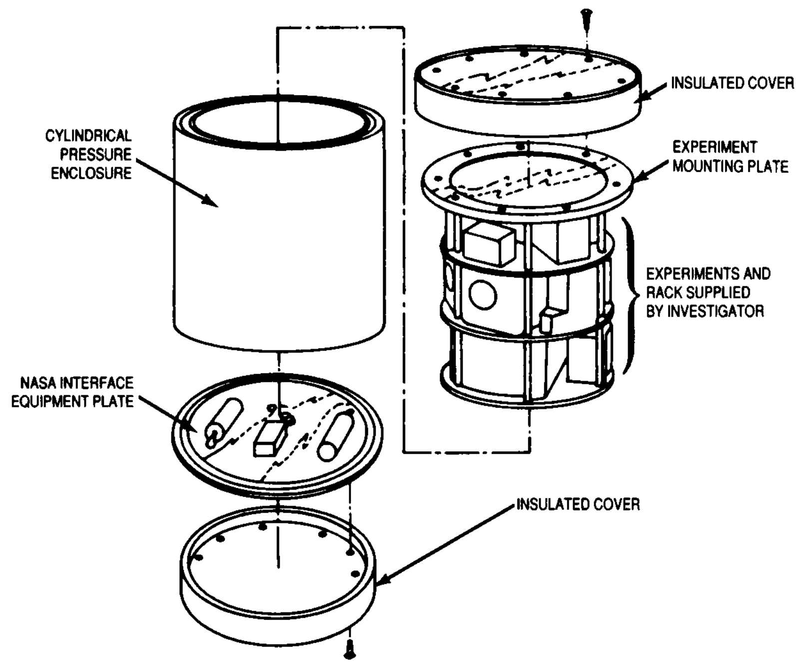
The EAC is mounted on the MSL carrier where it interfaces with the carrier's control and support subsystems.

- Special Interface Requirements: None
- Integration Options: The space in the EAC's base ring used for electrical and signal feedthroughs to the MSL carrier can be used for the experiment apparatus.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Get-Away-Special (GAS) Canister



Get-Away-Special Canister

Importance

After the major payloads have been scheduled for a Shuttle flight, some space for experiments may remain aboard the orbiter. To utilize the orbiter's full capacity, NASA has initiated the GAS canister program. GAS canisters are versatile, convenient carrier structures that allow small, self-contained experiments to be flown on a space-available basis. Through this program, public and private individuals and organizations from all countries have an opportunity to conduct scientific research and develop experiments aboard the orbiter at a modest cost.

GAS canister operations are independent of the orbiter, and experiments must be self-sufficient. GAS payloads do not draw upon any orbiter services other than three on/off controls activated by the crew. The experimenter is responsible for providing electrical power, heating/cooling, and data acquisition systems. The success of research performed in a GAS canister depends on the investigator's understanding of the orbiter environment during both suborbital and orbital microgravity conditions. During the design phase of a GAS payload, the investigator must consider thoroughly the effects of temperature, vibration, acoustics, acceleration, and pressure.

Method

The GAS canister is a standardized, cylindrical aluminum container with a short turnaround time. It can be evacuated and/or pressurized and includes an insulated exterior on the bottom and sides for thermal control. (An insulated top end cap is available.) A standard experiment mounting plate is used with each GAS canister. While this plate may not be altered, it does include adequate provisions for the attachment of experiment packages.

Orbiter Location

Payload Bay

Physical Characteristics

- Large GAS canister
  - Diameter: 50.20 cm
  - Length: 71.60 cm
  - Volume: 0.15 m^3
  - Maximum payload weight: 90.70 kg
- Small GAS canister
  - Diameter: 50.20 cm
  - Length: 35.89 cm
  - Volume: 0.06 m^3
  - Maximum payload weight: 27 to 45.40 kg

Operational Parameters

- A GAS payload can be pressurized, if required.
- Thermal control is passive.
- GAS canisters are battery powered.
- Six command functions are provided as a standard service.
- Other operational parameters are determined by the experiment developer.

Instrumentation

All instrumentation associated with experiments contained in GAS canisters will be provided by the investigator.

Data Acquisition

Attitude, time of operation, and orbital parameters are provided to experimenters; trajectory information from the orbiter can be purchased. Other data processing capabilities must be provided by the experiment.

Facility Integration

GAS canisters are payload bay facilities. Two or more payloads may be integrated into a GAS canister if they do not exceed weight limitations.

- Special Interface Requirements: NASA requires an interface equipment plate for container venting, purging, and command link connections; this plate may not be altered. After certain safety requirements have been met, NASA sends the investigator a shipping end plate on which the experiment is to be mounted and delivered to the integration facility. At the integration facility, the experiment is installed on the GAS flight end plate.
- Interface Options: GAS canisters can be mounted on a GAS adapter beam or on a bridge with other GAS canisters.

Additional Notes

Further information is available for potential GAS canister. users in the "Get-Away Special (GAS) Small Self-Contained Payloads Experimenter Handbook," a 1985 publication of the Goddard Space Flight Center, Special Payloads Division, Greenbelt, MD 20771.

Development Center

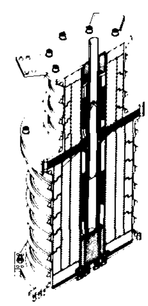
NASA Headquarters
Transportation Services/MCN
Washington, D.C. 20590
(202) 453-2538

Experiment Apparatus

The Space Transporation System (STS) has expanded significantly the periods of microgravity available to research scientists. This increased duration is particularly advantageous to investigations once hindered by gravity-induced disturbances, such as sedimentation, gravity-driven convection, and density differences.

Materials processing disciplines have benefitted especially from this enhanced environment for experimentation. Research in space processing of electronic materials, metals and alloys, and glasses and ceramics has indicated the potential to produce improved materials. Flight programs related to biotechnology, combustion science, and fluid dynamics have broadened horizons for both ground-based and spaceflight research in these disciplines as well.

A synopsis of these investigations and the experiment apparatus associated with each are listed below. Some apparatus are used by investigators in more than one discipline and are listed under each appropriate category. The fact sheet on an apparatus is located within the section under which it appears in boldface.

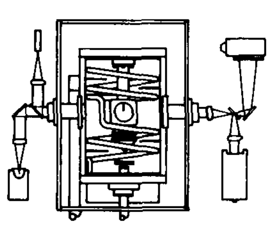


Crystal Growth Furnace

Electronic Materials

Improved electronic and electro-optical materials may be produced when the destabilizing effects of gravity-driven convection are reduced.

- **Advanced Automated Directional Solidification Furnace**
- **Crystal Growth Furnace**
- **Fluid Experiment Apparatus**
- **Fluid Experiments System**
- **Gradient Furnace for the Get-Away-Special Canister**
- MEPHISTO Apparatus
- Single Axis Acoustic Levitator
- **Vapor Crystal Growth System**

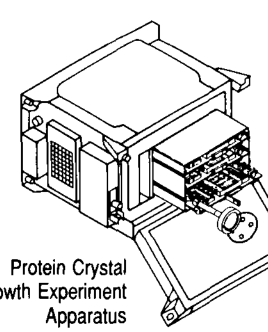


Isothermal Dendritic Growth Experiment Apparatus

Metals and Alloys

An unmasking of the influences of density differences and gravity-driven convection may lead to the production of new metallic alloys and composite materials.

- Advanced Automated Directional Solidification Furnace
- Acoustic Levitation Furnace
- Fluid Experiment Apparatus
- **Isothermal Dendritic Growth Experiment Apparatus**
- **MEPHISTO Apparatus**
- **Metals and Alloys Solidification Apparatus**



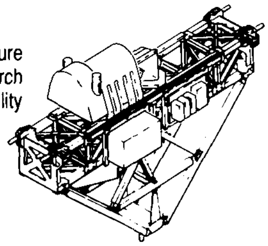
Protein Crystal Growth Experiment Apparatus

Biotechnology

In microgravity, the influences of thermal turbulence, buoyancy, and sedimentation are reduced, much to the advantage of investigations exploring protein crystal growth, the separation of biological materials, and cell culture.

- **Continuous Flow Electrophoresis System**
- Fluid Experiment Apparatus
- **Initial Blood Storage Experiment Apparatus**
- **Isoelectric Focusing Experiment Apparatus**
- **Monodisperse Latex Reactor System**
- **Protein Crystal Growth Experiment Apparatus**

Fluid Dynamics and Transport Phenomena

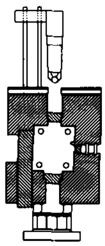


Low-Temperature Research Facility

Fluid dynamics is critical to all materials processes since, at some point in any process, materials exist in either a liquid or gaseous state and are subject to gravity-induced disturbances. The *elimination of these disturbances under* reduced gravitational influence allows scientists to characterize other phenomena active in materials processing.

- **Critical Fluid Light Scattering Experiment Apparatus**
- **Drop Physics Module**
- Fluid Experiment Apparatus
- Fluid Experiments System
- Gradient Furnace for the Get-Away-Special Canister
- **Low-Temperature Research Facility**
- **Surface Tension Driven Convection Experiment Apparatus**

Glasses and Ceramics

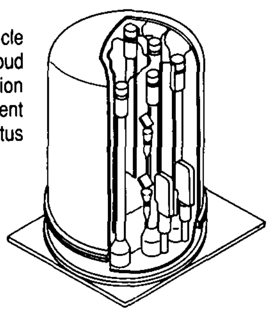


Single Axis Acoustic Levitator

In microgravity, certain materials can be processed without contact with another surface for longer periods and at higher temperatures than possible on Earth. This creates the possibility of producing purer glasses and ceramics for optical and electrical applications.

- **Acoustic Levitation Furnace**
- **Single Axis Acoustic Levitator**

Combustion Science



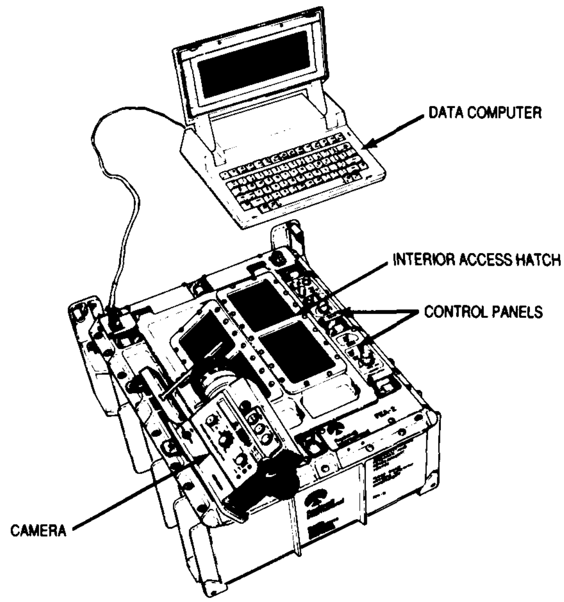
Particle Cloud Combustion Experiment Apparatus

A microgravity environment allows scientists to investigate fundamental phenomena that are associated with flame propagation, extinction, and control and that are masked by the influence of gravity on Earth.

- **Drop Combustion Experiment Apparatus**
- **Gas Jet Diffusion Flame Apparatus**
- **Particle Cloud Combustion Experiment Apparatus**
- **Solid Surface Combustion Experiment Apparatus**

The following fact sheets describe these experiment apparatus. Four categories of flight hardware are included: those that have flown aboard the STS; those that are flight qualified but have not yet been flown; those that are being refined for flight qualification; and those that are in conceptual design or developmental stages.

Fluid Experiment Apparatus (FEA)



Fluid Experiment Apparatus

Importance

The FEA is designed to provide industrial users with a convenient, low-cost, modular experiment system for fundamental space-processing research in biology, chemistry, and physics. With the FEA, investigators can conduct basic and applied processing or product development experiments in general liquid chemistry, crystal growth, fluid mechanics, thermodynamics, and cell culturing of biological materials and living organisms. This general-use, adaptable facility can be configured for a wide variety of experiments; the current configuration (FEA-1) will accommodate float zone crystal growth and certain fluid handling experiments.

Method

The FEA can manipulate gaseous, liquid, or solid samples, expose samples to vacuum conditions, and heat and cool samples. A number of specialized subsystems are planned for the FEA, including low-temperature air heaters, living organism incubators, high-temperature furnaces, custom-designed heaters, special sample containers, and a specimen centrifuge. These modules will allow FEA hardware and operations to be customized to support a wide range of experiment requirements.

Carrier

Orbiter middeck

Sample Summary

Specific experiment requirements determine the samples studied.

Physical Characteristics

- Self-contained
- Volume: 0.06 m^3
- Dimensions (LxWxH): 47.2 cm x 36.8 cm x 18.8 cm
- Weight capacity: 11.7 kg

Operational Parameters

- Voltage: 120 Vac at 400 Hz
- Can be connected to orbiter cooling and vacuum systems
- Other parameters determined by specific experiment requirements

Instrumentation

Specific experiment requirements determine the complement of instruments.

Data Acquisition

- Hewlett Packard 110 PC
- Variable frame-rate (1/60 to 36 sec) photographic recording system
- Additional data acquisition capabilities can be provided, e.g., sample temperature, pressure, viscosity.

Facility Integration

The FEA is mounted in the middeck in place of a modular stowage locker.

- Special Interface Requirements: None
- Integration Options: None

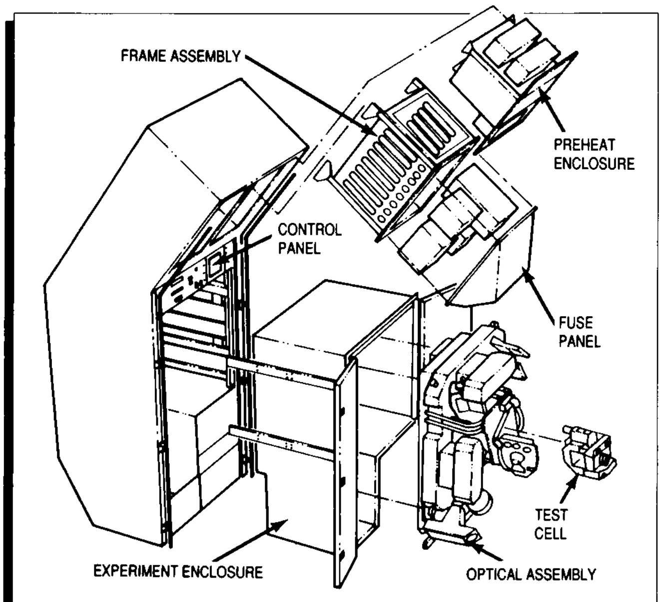
Additional Notes

The first flight of the FEA was on Shuttle mission 41-D in August 1984.

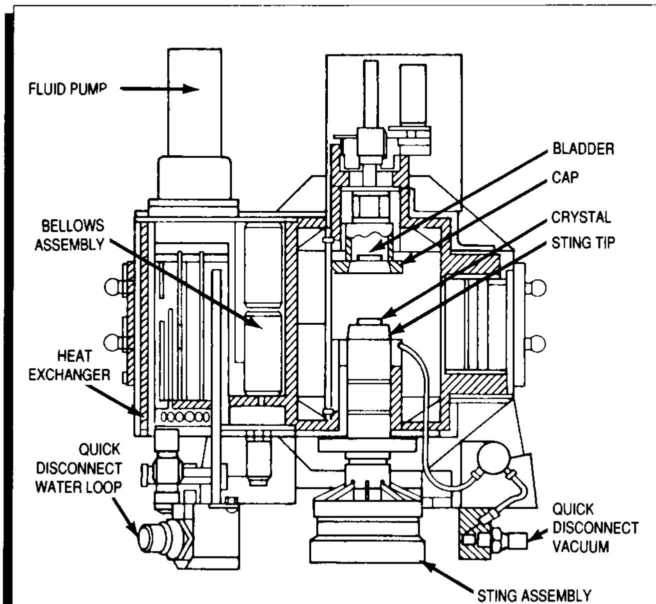
Development Center

Rockwell International
Space Processing
Mail Code FC46
12214 Lakewood Boulevard
Downey, CA 90241
(213) 922-4083

Fluids Experiment System (FES)



FES Rack Assembly



FES Test Cell Layout

Importance

The FES is a multipurpose fluids research apparatus for investigating the effects of microgravity on transparent fluids. It can be adapted for a variety of experiments in fluid convection, phase transition, bubble formation, immiscible fluids, and surface tension. In its current configuration, the FES is one of the first space facilities to allow crewmembers and investigators on the ground to monitor crystal growth continuously in microgravity. The system documents fluid processes during crystal growth from solution through innovative use of schlieren and holographic images, provides information on fluid processes that affect crystal growth on Earth and in space, and helps scientists understand how crystal defects form. The first crystals grown in the FES were of triglycine sulfate (TGS), a commercially important infrared radiation detector that does not require cooling below room temperature. Future experiments are planned to study solution crystal growth and casting with salts that model the actions of metals.

Method

A test cell containing a solution from which a crystal will be grown and a seed crystal cemented to a temperature-controlled finger, called a sting, are placed in the FES. If an investigation requires noncritical preheating of the growth solution, the FES has an enclosure in which one sample cell can be preheated while another is undergoing the majority of experiment operations on the optical bench. After preheating, a test cell is transferred mechanically to the optical bench; then, a cap-bladder that separates the seed crystal from the solution is removed, and experimentation begins. The seed crystal grows as solute from the growth fluid concentrates on its surfaces. As the experiment progresses, the concentration of the solution surrounding the crystal decreases, and the sting is programmed to cool the crystal so that a supersaturated solution will remain in contact with the growth surface, maintaining a constant growth rate.

During the experiment, the crew can adjust the experiment duration, temperature, and optical/holographic operations. The optical bench houses equipment for downlinking video of schlieren images to investigators on the ground. Holograms are made for postflight analysis, and an accelerometer located on the optical bench continuously measures the vibration environment.

Carrier

Spacelab

Sample Summary

- Length: 40 mm (maximum)
- Diameter: 30 mm (maximum)
- Operating temperature as implemented for TGS crystal growth (Other temperature ranges may be possible.)
  - Solution: 30 to 70 °C
  - Seed: 30 to 50 °C

Physical Characteristics

- The FES fits inside a Spacelab double rack.
- Optical test cell
  - Viewable volume: 10 cm^3
  - Additional volume is available for pumps or other mechanical apparatus.

Operational Parameters

- Video downlink: Black-and-white video of adjustable schlieren image
- Holography
  - Film capacity: 450 frames/transport, 3 transports available
  - Resolution: 20 microns - collimated beam (primary); 35 microns - 90-deg reflected beam (transverse)
- Temperature measurement and control
  - Temperature sensors (preheat) (11): 0.01- °C resolution
  - Temperature sensors (test cell) (25): 0.01- °C resolution
- Acceleration measurement: 3-axis, bidirectional
- Heat exchanger (water): ±0.5 °C/min
- Power: 1.4 kW (maximum), 700 W (average)

Instrumentation

- Closed-circuit television with remote to ground
- Adjustable schlieren system
- 70-mm holographic recorder
- Accelerometer
- Process Control and Data Acquisition (PCDA) microprocessor

Data Acquisition

The PCDA microprocessor provides all data processing requirements (up to 1 sample per second per parameter) and transmits directly to the Spacelab high-rate multiplexer for downlink.

Facility Integration

The FES is mounted in a Spacelab double rack; miscellaneous hardware items are located in Spacelab stowage.

- Special Interface Requirements: The FES utilizes the Spacelab-provided water cooling loop, rack cooling air, and vacuum. The FES connects electrically to the high-rate multiplexer and the Spacelab video switch.
- Integration Options: None

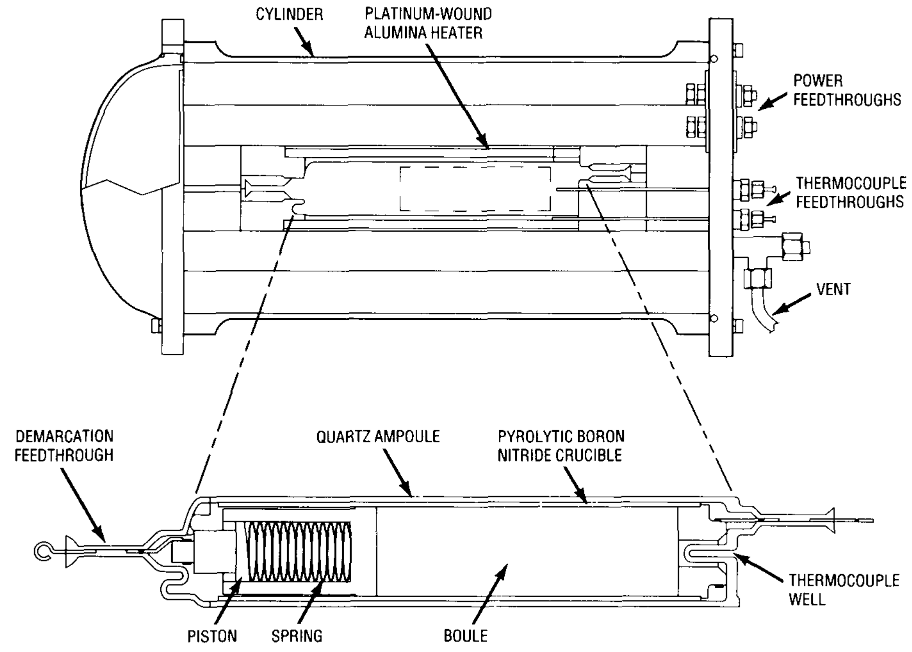
Additional Notes

The FES performed satisfactorily on Spacelab 3 in May 1985 on its first flight with the TGS experiment.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Gradient Furnace for the Get-Away-Special Canister (GFGAS)



Gradient Furnace for the Get-Away-Special Canister

Importance

The GFGAS has been developed to provide a low-cost, quick-turnaround furnace for fundamental studies of transport phenomena in crystal growth processes. The furnace recrystallizes a previously grown gallium arsenide (GaAs) crystal by thermal gradient transport. Consistently uniform, high-quality GaAs crystals may prove to be the basis for a new high-speed semiconductor technology; however, Earth-based processing is limited in its ability to produce crystals of this quality. Experimentation in microgravity may make it possible for scientists to define the contributions of gravity-driven convection on the types and distribution of defects in these semiconductor crystals. The demonstration of significant improvements in the quality of space-grown crystals may lead to improved Earth-based processing or space-based production of such materials.

Method

This apparatus has two identical furnaces; in each, an Earth-grown GaAs seed crystal is melted back to 2.54 cm (nominally), then regrown from the remaining seed to 7.62 cm. The recrystallization is accomplished by directionally solidifying the sample as a thermal gradient is translated along the furnace. Each furnace incorporates a pair of independent microcomputers for thermal control, experiment sequencing, and data logging. Accelerations are monitored during each regrowth with a dedicated three-axis acceleration system. One ampoule provides for interface demarcation of the sample during regrowth. The demarcation data provide absolute growth rate data and record the instantaneous interface shapes during the demarcation pulses. The furnaces share a single battery-based power supply that provides adequate power for two sequential 8-hour regrowth cycles. Space-grown GaAs crystals are analyzed for type and distribution of defects, distribution of dopants and impurities, and the level and uniformity of selected electrical properties. These data are compared with data from crystals grown by the same technique on Earth to determine the effect of gravity-driven transport on the solidification process.

Carrier

GAS canister mounted in orbiter payload bay

Sample Summary

• Capacity/flight:	2 independent samples
• Length:	10 cm
• Diameter:	22 mm

Physical Characteristics

• GAS Canister	
- Dimensions (H x dia.):	71.76 cm x 50.80 cm
- Volume:	0.15 m^3
• Gradient Furnace	
- Dimensions (H x dia.):	60.96 cm x 50.16 cm
- Weight:	90 kg

Operational Parameters

• Power:	Approximately 150 W (peak); 3 kWh (total available)
• Voltage (furnace):	48 Vdc
• Temperature:	1,330 °C (maximum)

Instrumentation

The GFGAS control and data system is based on seven single-board microcomputers that use a CMOS 6303 processor. Each microcomputer is programmable in BASIC and provides 11 channels of 10-bit analog-to-digital input, 16 channels of digital input/output, and 32-Kbyte Random Access Memory (RAM) (increased to 150 Kbyte for the three channels of accelerometer data) for program/data storage.

Three orthogonal acceleration sensors record peak event and average environment records in the range of 10^{-5} to 10^{-2} g/g_0 at frequencies to 16 Hz.

Data Acquisition

All data are stored on RAM in the seven microcomputers. The furnace control computers log control temperature and power level after each control cycle. Battery voltage, current, six furnace thermocouple temperatures, and one thermistor temperature are recorded every 2 minutes during the regrowth cycle. Additional housekeeping data are recorded intermittently.

Facility Integration

The gradient furnace is designed specifically for installation in the GAS canister.

- Special Interface Requirements: None
- Integration Options: None

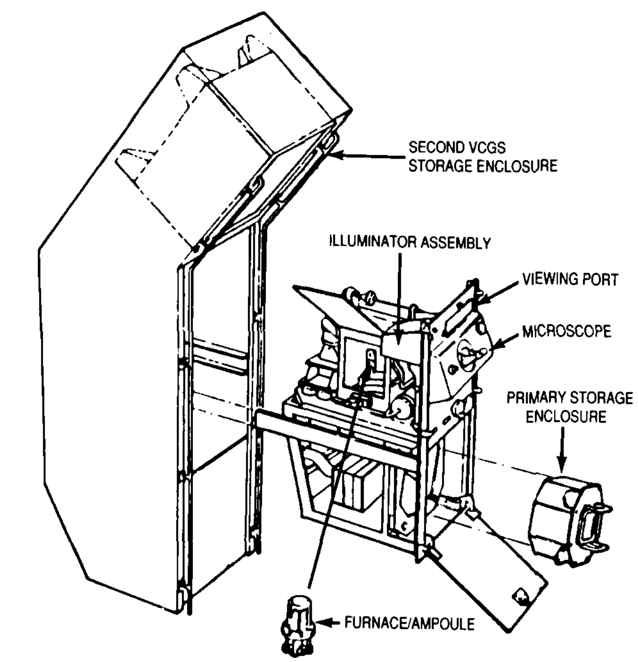
Additional Notes

The GFGAS hardware is being developed by GTE Laboratories under contract to NASA/Lewis Research Center. The project is funded jointly by NASA, the U.S. Air Force, and GTE.

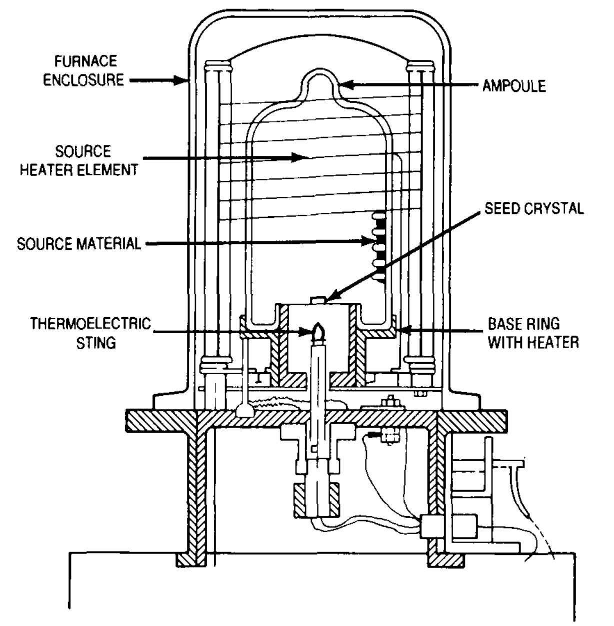
Development Center

NASA/Lewis Research Center
Space Experiments Division
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-2864

Vapor Crystal Growth System (VCGS)



VCGS Rack Assembly



VCGS Module Elements

Importance

The VCGS is used for crystal growth, one of the most promising fields in microgravity materials processing. When crystals are grown on Earth, gravity-related stresses often cause defects that impair the quality of the crystal for high-technology uses. If the disruptive forces are eliminated or reduced in microgravity, it may be possible to produce the higher quality crystals needed for many technical applications. The VCGS gives scientists the hands-on control necessary to grow high-quality crystals. Crewmembers in space and investigators on the ground can continuously monitor and adjust growth parameters, much as they do in ground-based laboratories. This apparatus permits long-duration crystal growth experiments, and samples are returned to investigators for detailed analysis. (A mercury iodide crystal grown during the Spacelab 3 mission for more than 100 hours is superior to similar terrestrial crystals. Mercury iodide crystals are valuable as nuclear radiation detectors.)

Method

Crystals are grown in the VCGS apparatus by the vapor transport method. The source material to be vaporized, the seed crystal to which the evaporate will migrate, and the ampoule in which they are contained are maintained at different temperatures by three heating elements. The seed crystal is cooled by radiation to a thermoelectric element so that hot vapors from the source material will crystallize on its surface. A crewmember monitors the growth process and can adjust the temperature of the VCGS elements to control the crystal growth. Scientists on the ground observe the growth on downlinked closed-circuit television. The space-grown crystal is returned for postmission analysis and comparison with crystals grown by the same method on Earth.

Carrier

Spacelab module

Sample Summary

- Ampoule diameter: 8.0 cm
- Ampoule length: 11.0 cm
- Ampoule strength: 1.5 atm at 180 °C (minimum)
- Test chamber air loop (adjustable): 20 to 30 °C ±1 °C

Physical Characteristics

The VCGS furnace/ampoule and associated instrumentation are mounted on an equipment drawer. This drawer is located directly above the storage enclosure in which the furnace/ampoule is contained during launch, reentry, and landing. A second furnace/ampoule is stored in another enclosure at the top of the rack.

Operational Parameters

- Source heater range: 100 to 120 °C
- Ring heater range: 120 to 180 °C
- Sting heater range: 40 to 80 °C

These temperature parameters, defined for mercury iodide crystal growth, may be changed to grow other types of crystals.

Instrumentation

The VCGS apparatus contains a 10-30x binocular microscope designed for viewing the crystal from extended working distances, a closed-circuit television, a mechanical rotation stage that allows the crystal to be viewed from all sides, and electronics for temperature measurement and heater control.

Data Acquisition

The VCGS can acquire data only when used in conjunction with the Fluid Experiments System (FES), whose microprocessor handles all time/temperature control requirements and transmits status data directly to the Spacelab high-rate multiplexer for downlink to the ground for data recording.

Facility Integration

The VCGS is installed in a Spacelab single rack adjacent to the FES and uses standard Spacelab interfaces. It is designed to be flown with the FES and relies on the FES for power control and distribution and for process control.

- Special Interface Requirements: None
- Integration Options: None

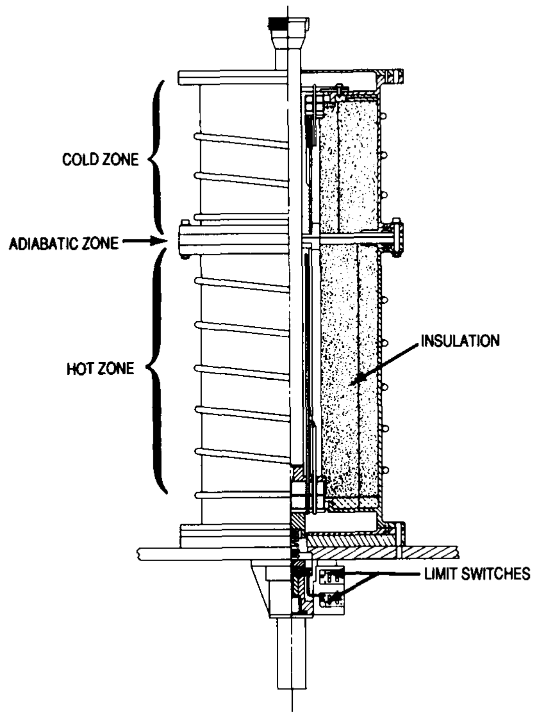
Additional Notes

The VCGS apparatus was very successful on its first flight on Spacelab 3 in May 1985.

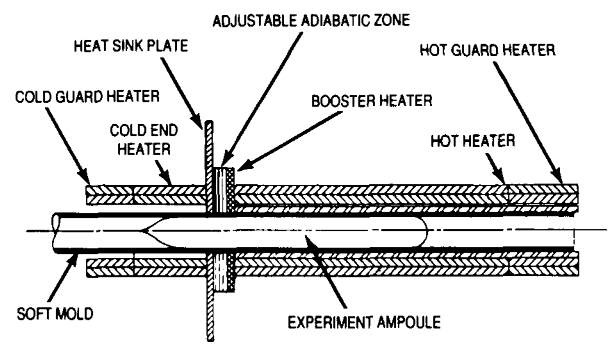
Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
Marshall Space Flight Center, AL 35812
(205) 544-1966

Advanced Automated Directional Solidification Furnace (AADSF)



Advanced Automated Directional Solidification Furnace (Furnace Module)



AADSF Furnace Zone Arrangement

Importance

The AADSF is a second-generation directional solidification furnace that will be used to develop processes for growing high-quality crystals for electro-optical materials and for producing metals and alloys. The furnace's advanced design for improved temperature control between a sample's hot and cold ends allows a nearly planar interface to be maintained between the melt and solid states of a sample alloy. This feature expands the capabilities of studies that examine how gravity limits the melt growth of alloys and how convection caused by density and temperature differences influences the homogeneity and defects of a crystal. A better understanding of these phenomena is necessary to improve processing of alloys and crystals on Earth and to develop more sophisticated space processing facilities.

Method

The AADSF consists of a Furnace Container (FC), a Signal Conditioning and Control System (SCCS), and a Data Acquisition System (DAS). The FC contains a multizone furnace and a mechanism that moves the sample through the furnace; the SCCS controls the AADSF and conditions the measurement data; and the DAS processes the experiment data for recording or downlink. The furnace may be configured for an individual experimenter's sample and then commanded to compensate for changes in temperature as the sample adjusts to its steady-state value, changes in thermal conductivity between solid and melt, and energy deposition from sample translation and release of latent heat. In future experiments, the solid/melt interface will be marked at various times during experiment processing.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

- Capacity/flight: 1 sample/flight
- Ampoule outer diameter: 2.0 cm (maximum)
- Ampoule length: 25.0 cm
- Ampoule inner diameter: Experiment specific

Physical Characteristics

- Furnace container dimensions (H x dia.): 130 cm x 43 cm
- Furnace assembly weight: 213 kg

Operational Parameters

• Power	
- Furnace:	775 W (peak at 1,600 °C)
- SCCS:	119 W (peak)
- DAS:	80 W
• Voltage (SCCS):	28 ±4 Vdc
• Cold zone operating temperature:	200 to 850 °C
• Hot zone operating temperature:	200 to 1,500 °C
• Booster heater:	200 to 1,620 °C
• Cold zone length:	12.70 cm
• Hot zone length:	25.40 cm
• Booster heater length:	0.05 cm
• Translation system	
- Translation distance:	24.0 cm
- Translation rate:	0.5 to 50.0 mm/h
- Number of rate changes:	2 to 10
- Rate range insertion/removal:	500 mm/h (minimum)

Instrumentation

- Motion-control programmer (*sample positioning and control*)
- AADSF controller (central processing unit, power electronics, housekeeping)

Data Acquisition

- Thermocouple direct temperature measurements (6)
- Furnace temperature versus time
- Temperature rate versus time
- Translation rate versus time
- Sample position versus time

Facility Integration

The AADSF is housed in an Experiment Apparatus Container (EAC), which is mounted on the MSL in the orbiter payload bay.

- Special Interface Requirements: Use of coldplate under furnace EAC and the SCCS housing
- Integration Options: None

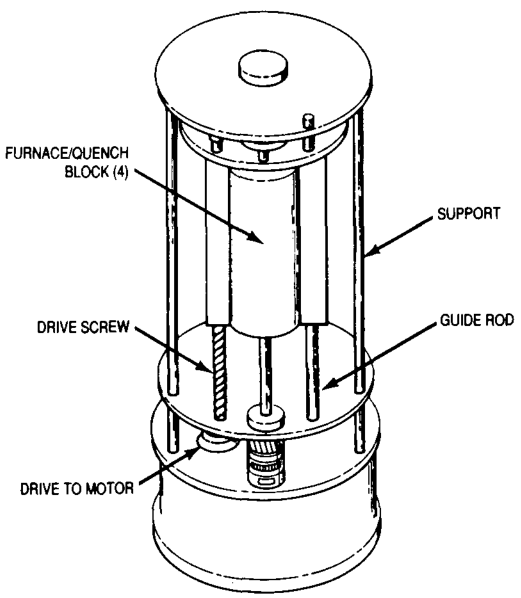
Additional Notes

An engineering prototype has been completed; the first flight of the AADSF is planned for 1992.

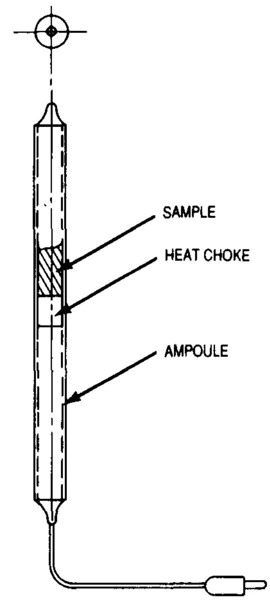
Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
Marshall Space Flight Center, AL 35812
(205) 544-1966

Automated Directional Solidification Furnace (ADSF-I)



Automated Directional Solidification Furnace



ADSF Ampoule

Importance

Composite materials, called eutectics, often have properties different from and superior to those of the individual components in the mixture, and materials that have been directionally solidified may exhibit great strength along the axis or direction of solidification. The ADSF-I apparatus allows experimenters to investigate the unusual electrical, magnetic, and optical properties of directionally solidified molecular structures. The roles of convection and other gravity-related phenomena, important factors in the processing of these composite materials, are being defined by microgravity experiments. If, as a result of microgravity experimentation, convection phenomena in directional solidification can be better controlled, mixtures with enhanced properties may be produced and new ones may be identified.

Method

The ADSF-I apparatus has four separate heating units with individual heaters and quench blocks to melt and cool up to four different material samples individually. A heating unit translates along the long axis of the sample during the melt process, and each sample is then cooled at a controlled rate by a water-cooled copper quench block, which promotes directional solidification. Each furnace can be programmed for up to two cooling rate changes during sample processing. Furnace translation speeds are selected and preset during prelaunch test and checkout, i.e., two fixed translation gear ratios can be specified and incorporated into the drive chain before apparatus closeout for launch. These ratios, however, cannot be changed later. The sealed furnace enclosure maintains atmospheric and environmental conditions.

Carrier

Orbiter middeck

Sample Summary

• Capacity/flight:	4 (1 sample/furnace)
• Ampoule outer diameter:	6 to 8 mm
• Ampoule length:	35 cm
• Sample length:	Determined by the selected furnace translation rate and mission time
• Sample diameter:	4 mm (assumes ampoule with a 4-mm inner diameter)

Physical Characteristics

- Furnace Container dimensions (H x dia.): 49.4 cm x 44.9 cm
- Furnace Container weight: 36 kg

Operational Parameters

- Furnace Assembly
  - Number/Furnace Container: 4
  - Number ampoules/assembly: 1
  - Temperature: 200 to 500 °C
  - Translation rate: 0.1 mm/h to 500 mm/h
  - Thermocouples/sample: 4
- Power: 28 ±4 Vdc, 10 A
- Power Profile
  - Turn-on: 260 W
  - Processing: 150 W
  - Cooldown: 15 W

Instrumentation

- Thermocouples
  - Furnace control/status
  - Sample temperature(s)
- Measurements are recorded only, not downlinked.

Data Acquisition

- 22 analog-to-digital channel inputs
- Time tag: Data recording of analog to digital with relative time tag
- Data rates: 1.0, 0.5, and 0.25 samples/second and 1.0 sample/minute using any mix of sample rates in a 1-minute period
- Storage: 8 or 12 most significant bits

Facility Integration

When flown as a middeck payload, the ADSF-I is integrated in the aft bulkhead. The apparatus and its components require a minimum space equivalent to that occupied by five adjacent middeck lockers.

- Special Interface Requirements
  - Electrical: Flight system requires a 28 ±4-Vdc external power source.
  - Operations: System requires crew support to initiate experiment turn-on/off and to initiate each of the four experiment runs.
- Integration Options: More than the equivalent of five middeck lockers may be required.

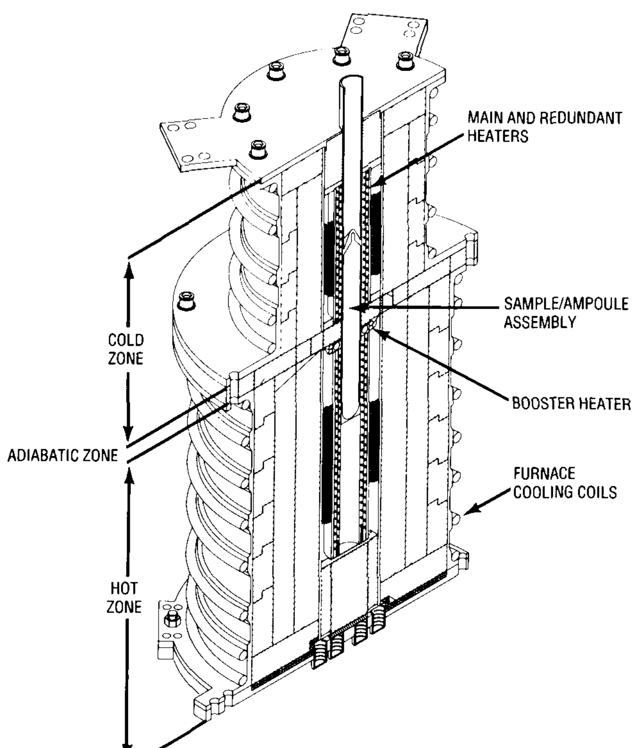
Additional Notes

The ADSF-I flew on Shuttle mission 51-C.

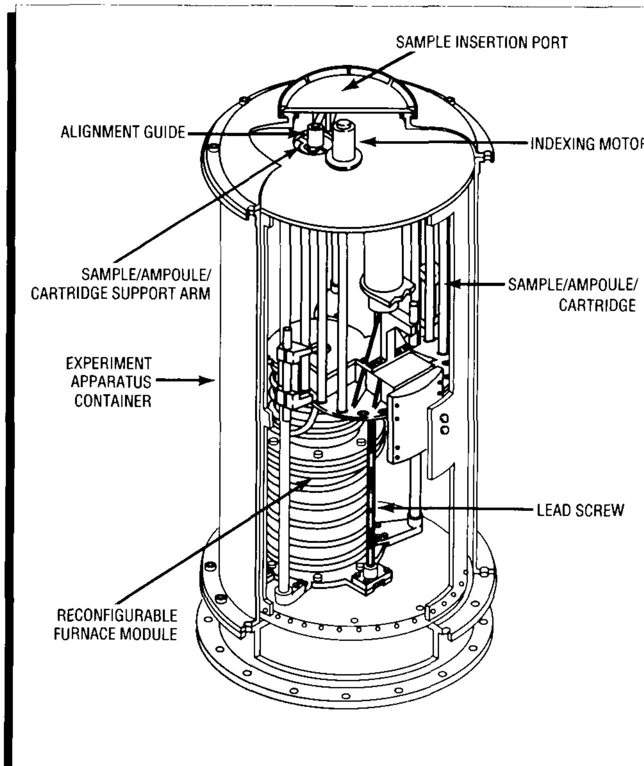
Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Crystal Growth Furnace (CGF)



Crystal Growth Furnace



CGF in Experiment Apparatus Container

Importance

The CGF is an improved, modular directional solidification furnace that will process larger samples of semiconductor materials than earlier furnaces, allow on-orbit exchange of samples by a crewmember, and permit premission module reconfiguration to accommodate a variety of experiment requirements. The CGF will perform precursor experiments useful in designing experiments and hardware for a space station semiconductor crystal growth facility.

Method

The CGF consists of the Integrated Furnace/ Experiment Apparatus Container Assembly, which includes the Reconfigurable Furnace Module (RFM), the Furnace Translation Mechanism (FTM), the automated Sample Exchange Mechanism (SEM) that can process up to 6 samples automatically, and the Furnace Support Structure assembly. These components are housed in an Experiment Apparatus Container (EAC) and are supported by an environmental control system and an avionics subsystem. The heating zones include redundant heating elements. A booster heater is provided at the interface between the hot zone and the adiabatic zone to provide better control of the temperature gradient. The adiabatic zone thickness can be varied, and a heat extraction plate can be included to obtain steeper gradients. Interface demarcation will be available either by mechanical or Peltier pulsing methods.

The furnace translates over the sample length to minimize induced accelerations. A crewmember manually changes out samples, thus increasing the number of samples that can be processed during a mission. Sample processing is fully automatic and can be monitored and controlled by investigators on the ground.

Carrier

Spacelab

Sample Summary

- Length: 20 cm
- Diameter: Up to 2 cm
- Containment: Ampoule and/or cartridge assembly

Physical Characteristics

- EAC (dia. x H): 60.9 cm x 162.5 cm
- Furnace module (dia. x H): 23.1 cm x 63 cm
- Optional heat extraction plate
- Sample/ampoule/cartridge failure detection
- View port for sample/ampoule/cartridge integrity verification
- Manual and/or automatic sample changeout capability

Operational Parameters

- Power: 1,250 W
- Voltage: 28 ±4 Vdc

Temperature

- Hot zone: 200 to 1,600 °C
- Cold zone: 200 to 1,300 °C
- Booster zone: 200 to 1,700 °C
- Adiabatic zone: Variable; 0.5 to 7.0 cm thick
- Heating rate: Up to 300 °C/h
- Translation rate: 0.004 to 8.30 mm/min
- Absolute control setpoint accuracy: ±4 to 9 °C, depending on selected temperature range and thermocouple type
- Absolute control setpoint stability: ±0.5 °C
- Processing atmosphere: Argon

Instrumentation

- Sample thermocouples: 6
- Control thermocouples: 2/heater; 14 total
- 6-sample SEM
- Pressure transducers
- Flow sensors
- Humidity sensors
- Limit switches
- Tachometer
- Voltage, current, and power sensors

Data Acquisition

- CGF-provided Control and Data Acquisition System
- Real-time data recording and downlink

Facility Integration

The CGF will be located in an EAC in the Spacelab habitable module and ultimately in the space station.

- Special Interface Requirements: The CGF EAC will interface with the appropriate Spacelab mounting, power, command and data handling, and environmental control services offered to experiments.
- Integration Options: None

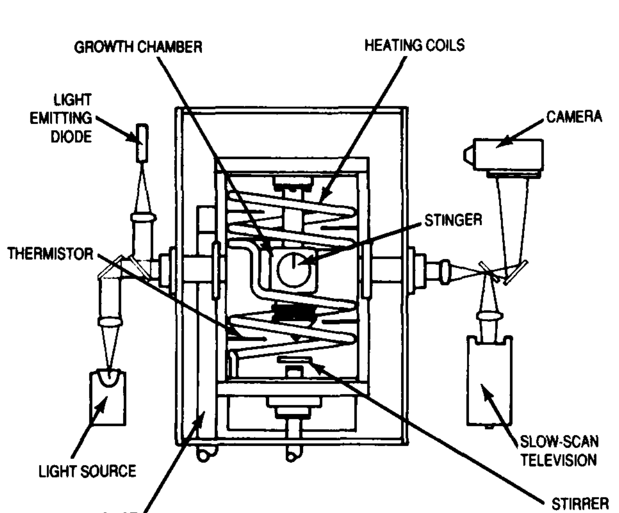
Additional Notes

The CGF has completed the Preliminary Requirements Review.

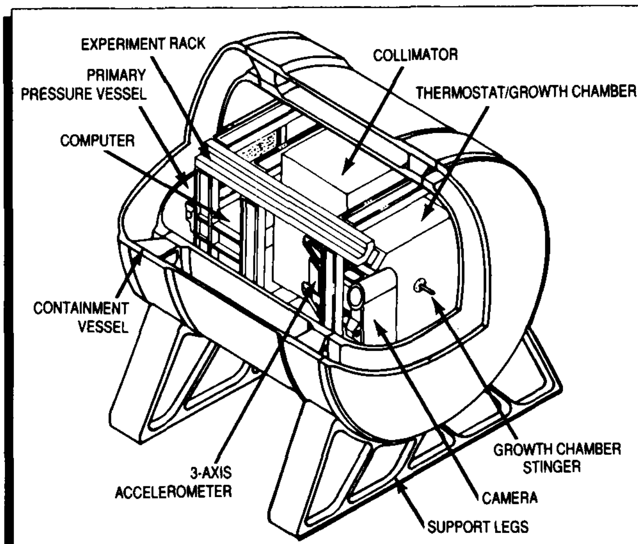
Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
Marshall Space Flight Center, AL 35812
(205) 544-1966

Isothermal Dendritic Growth Experiment (IDGE) Apparatus



Isothermal Dendritic Growth Experiment Apparatus



IDGE Assembly

Importance

The IDGE apparatus enables investigators to study the growth of dendrites, crystals that are shaped like pine trees, in organic materials that simulate pure metal and metal alloy systems. By testing the validity of mathematical models, IDGE investigations will contribute to advances in metallurgical processing and to the production of metals with enhanced properties.

The IDGE apparatus allows investigators to measure dendritic growth in microgravity where heat transfer is a more dominant factor in crystallization than fluid motion and to study the effects of melt supercooling and acceleration on dendritic growth rate, tip radius, side branch spacing, and general morphology. The materials studied are transparent, crystalline organics such as pure succinonitrile (SCN) and SCN alloys, which solidify with a cubic crystal structure similar to iron.

Method

Within the IDGE, a sample is contained in an isothermal growth chamber, where it is first melted and then supercooled with an accuracy of ±0.002 K. Next, growth of a dendrite is initiated in the center of the growth chamber at the tip of a capillary injector. The growth of the dendrite is recorded photographically on two orthogonal 35-mm single lens reflex cameras and also with a slow-scan television system that sends real-time images to investigators on the ground. During a given flight, the material can be remelted and dendrites can be regrown at up to 20 different supercool temperatures. Postflight, a computerized image analyzer extracts velocity, radii, and side branch data from the photographs.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

- Capacity/flight: 1 chamber
- Chamber outer diameter (spherical): 5 to 7 cm
- Sample diameter (spherical): 4 to 6 cm
- Sample volume: 11 to 35 cm^3
- Sample material: Transparent, crystalline SCN or similar material

Physical Characteristics

- Dimensions (LxWxH): 45 cm x 60 cm x 45 cm
- Weight: less than 100 kg
- Volume: 0.12 m^3
- Temperature: 30 to 60 °C

Operational Parameters

• Chamber operating temperature:	30 to 60 °C
• Photographic field of view:	6 mm x 8 mm (typical)
• Photographic resolution:	2 to 5 micrometers
• Film frames (2 cameras):	250/camera
• Remelt/growth cycles per flight:	20 (typical)
• Power:	Less than 300 W
• Voltage:	28 Vdc

Instrumentation

- Automatic computer control system
- High-precision/accuracy thermometry
- Dendrite growth detection, electrically and optically
- 3-axis accelerometer
- Data storage
- Real-time slow-scan television
- 35-mm cameras (2)

Data Acquisition

- Recording data on film below crystal image
- Computer with Programmable Read-Only Memory storage
- Space Acceleration Measurement System for recording accelerations on optical disks
- MSL Experiment Tape Recorder
- Data downlink (including low-resolution, slow-scan television image of dendrite) by way of MSL and orbiter systems

Facility Integration

The IDGE apparatus is designed to be housed in an Experiment Apparatus Container (EAC) and integrated for flight on the MSL.

- Special Interface Requirements: The IDGE device interfaces with standard MSL structural, power, data handling, and environmental control services.
- Integration Options: The IDGE can fly on a carrier similar to MSL if that carrier has equipment for measuring accelerations. With substantial modification, a version with reduced capability could fly in Spacelab or the orbiter middeck.

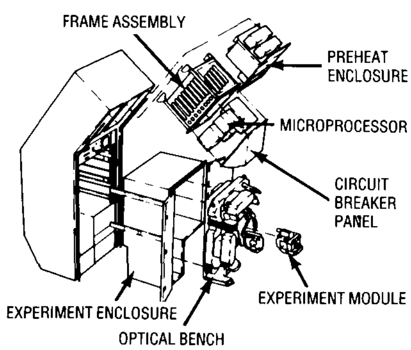
Additional Notes

The IDGE apparatus is being designed and built at Lewis Research Center. Two flight units are to be built, and an extra climate-controlled EAC will be built from spares if these are not needed for the first two units.

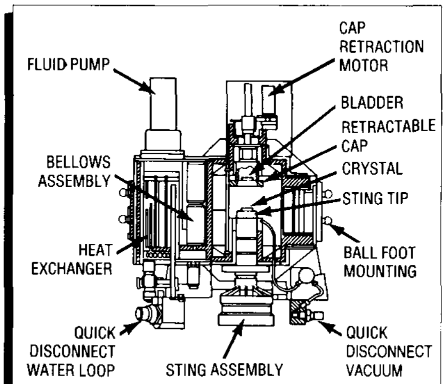
Development Center

NASA/Lewis Research Center
Space Experiments Division
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-2864

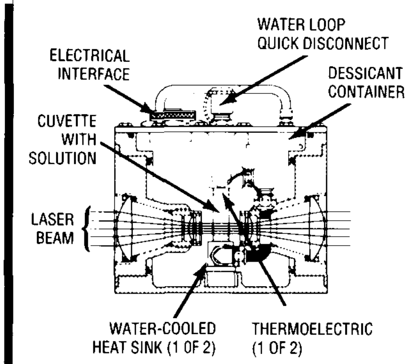
Fluid Experiments System (FES)



FES Rack Assembly



TGS Experiment Module Layout



CAST Experiment Module Layout

Importance

The FES is a multipurpose fluids research apparatus for investigating the effects of microgravity on transparent fluids. It can be adapted for a variety of experiments in fluid convection, phase transition, bubble formation, immiscible fluids, and surface tension. The FES is one of the first space facilities to allow crewmembers and investigators on the ground to monitor crystal growth continuously in microgravity. In one experiment module, the system documents fluid processes during crystal growth from solution through innovative use of schlieren and holographic images, provides information on fluid processes that affect crystal growth on Earth and in space, and helps scientists understand how crystal defects form. The first crystals grown in the FES were of triglycine sulfate (TGS), a commercially important infrared radiation detector that does not require cooling below room temperature. A second experiment module has been developed for experiments that study solidification and casting with aqueous solutions of salts that model the actions of metals.

Method

The TGS experiment module contains both a solution from which a crystal will be grown and a seed crystal attached to a temperature-controlled finger called a sting. A retractable cap protects the seed from the solution before and after the crystal growth operation. A preheat enclosure is used for the non-critical operation of dissolving all solute, which can be done in parallel with crystal growth operations in another cell on the optical bench (OB). The experiment is initiated on the OB by retracting the cap when all conditions in the solution are appropriate. The seed crystal grows by removing solute from the supersaturated solution. As the growth progresses, the concentration of the solution surrounding the crystal decreases; therefore, the sting must be programmed for additional cooling so that the solution around the crystal will remain supersaturated to maintain a constant crystal growth rate.

The Casting and Solidification Technology (CAST) experiment module consists of a cuvette containing an aqueous solution of ammonium chloride, which duplicates the solidification process of metals. The temperature of the ends of the cuvette are independently controlled by thermoelectric devices. The temperature of both ends of the cuvette is raised above the saturation temperature to dissolve all crystallites; a temperature gradient is established in the cuvette; and the temperature at both ends is lowered in a controlled manner so that diffusion and growth can be studied as a function of temperature gradient and growth rate.

The crew can adjust the experiment duration, temperatures, and optical/holographic operations during experiments in either experiment module in real time. The OB houses equipment for downlinking video of schlieren images to investigators on the ground and for recording holograms of the cells that are reconstructed postflight. An accelerometer located in the FES continuously measures the vibration environment.

Carrier

Spacelab

Sample Summary

- Length: 40 mm (maximum)
- Diameter: 30 mm (maximum)
- Operating temperature as implemented for TGS crystal growth (Other temperature ranges may be possible.)
  - Solution: 30 to 70 °C
  - Seed: 30 to 50 °C

Physical Characteristics

- The FES fits inside a Spacelab double rack.
- Optical experiment module
  - Viewable volume: 10 cm^3
  - Additional volume is available for pumps or other mechanical apparatus.

Operational Parameters

• Video downlink:	Black-and-white video of adjustable schlieren image
• Holography	
- Film capacity:	450 frames/transport, 3 transports available
- Resolution:	20 μ - collimated beam (primary); 35 μ - 90-deg reflected beam (transverse)
• Temperature measurement	
- Number of channels:	15 (preheat); 30 (OB)
- Range:	0 to 200 °C
- Resolution:	0.01 °C
• Acceleration measurement:	3-axis, bidirectional
• Heat exchanger (water):	25 to 90 °C range
• Power:	1.4 kW (maximum), 700 W (average)

Instrumentation

- Closed-circuit television with remote to ground
- Adjustable schlieren system
- 70-mm holographic recorder
- Accelerometer
- Process Control and Data Acquisition (PCDA) microprocessor

Data Acquisition

The PCDA microprocessor provides all data processing requirements (up to 1 sample per second per parameter plus 300 samples per axis for the accelerometer) and transmits directly to the Spacelab high-rate multiplexer for downlink.

Facility Integration

The FES is mounted in a Spacelab double rack; miscellaneous hardware items are located in Spacelab stowage.

- Special Interface Requirements: The FES utilizes the Spacelab-provided water cooling loop, rack cooling air, and vacuum. The FES connects electrically to the high-rate multiplexer and the Spacelab video switch.
- Integration Options: None

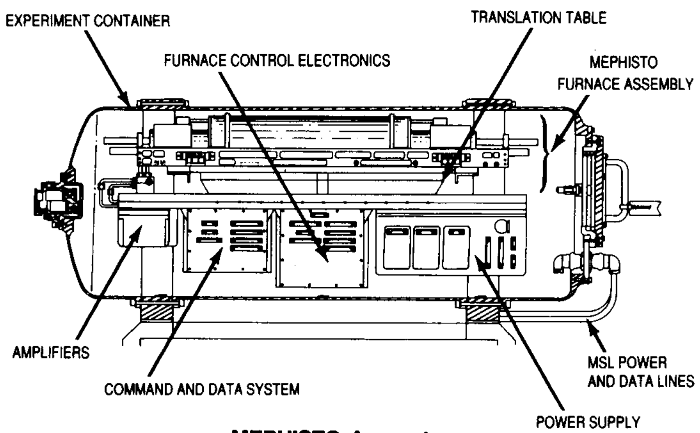
Additional Notes

The FES performed satisfactorily on Spacelab 3 in May 1985 on its first flight with the TGS experiment.

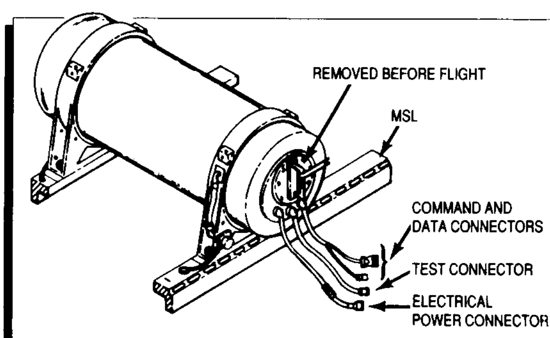
Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
Marshall Space Flight Center, AL 35812
(205) 544-1966

MEPHISTO Apparatus



MEPHISTO Apparatus



MEPHISTO Experiment Container

Importance

The MEPHISTO apparatus is a sophisticated furnace for basic research that will define the influence of various parameters on the directional solidification of metallic alloys and doped semiconductors. In this apparatus, the relationship between crystal growth and fluid flow in the sample, a phenomenon difficult to examine on Earth, can be characterized. It is unique in that investigators can make real-time measurements and analyses and, in response to findings, can vary the conditions under which experimentation occurs. The MEPHISTO apparatus allows many cycles of solidification and remelting and is particularly well adapted for long-duration missions.

Method

The MEPHISTO apparatus will process three stationary, rod-shaped samples simultaneously within its heater/cooler configuration. The furnace is brought to a predetermined temperature and then moved along the length of the samples at a specified rate. Experimenters are able to study several melts and solidifications under varying conditions. As the right section of the furnace, which is mounted on a sliding mechanism, is driven toward the fixed, left section, the samples are monitored, one for the solid/liquid interface temperature, a second for interface shape marking, and the third for quenching. A metallic film, which couples the sample ends with 60 °C heat sinks, and MEPHISTO's superinsulation make very high gradients possible within each sample.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

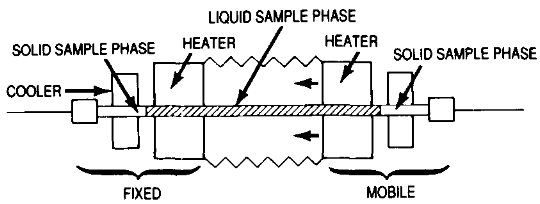
- Capacity/flight: 3 samples/flight
- Length: 760 mm
- Diameter: 10 mm

Physical Characteristics

- Sample container: Quartz ampoule
- Solidification length: 180 mm
- Solidification velocity: 10^{-6} to 10^{-3} cm/min
- Weight: 164.3 kg or less

Operational Parameters

- Heater power: 860 W (peak); 500 W (continuous)
- Voltage: 28 ±4 Vdc
- Operating furnace atmosphere: Vacuum
- Operating sample temperature range: Up to 1,170 K
- Maximum temperature gradient: 300 K/cm
- Quenching: Up to 3 cm length at up to 150 K/sec, depending on material and crucible characteristics



MEPHISTO Schematic

Instrumentation

- Thermocouples
- MSL accelerometer

Data Acquisition

Data are recorded on the MSL Experiment Tape Recorder and downlinked in real time to investigators during the mission.

Facility Integration

The MEPHISTO apparatus has been designed for integration on the MSL.

- Special Interface Requirements: A unique experiment container has been developed to house the MEPHISTO apparatus on the MSL.
- Integration Options: None

Additional Notes

The MEPHISTO scientific program is a cooperative effort between the French Centre National d'Etudes Spatiales (CNES) and NASA. Fabrication of the MEPHISTO flight hardware has begun.

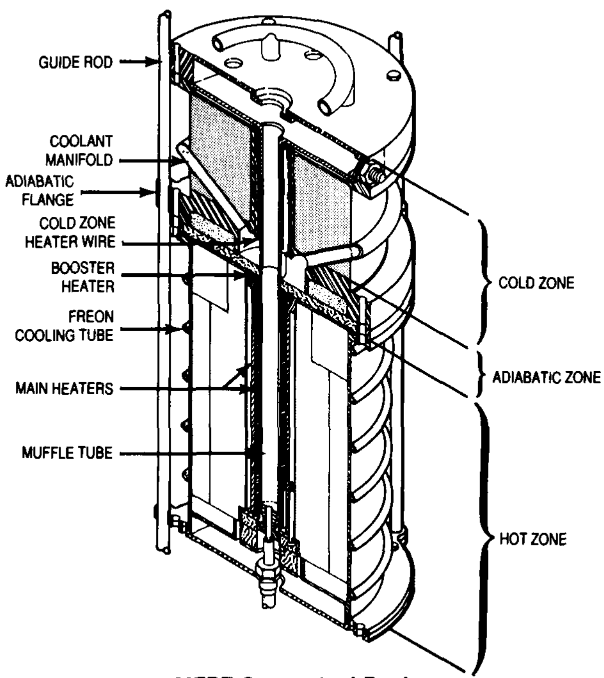
Development Center

Centre National d'Etudes Spatiales
Centre Spatial de Toulouse
CT/SCM/USS/GERME
31055 Toulouse, CEDEX
France

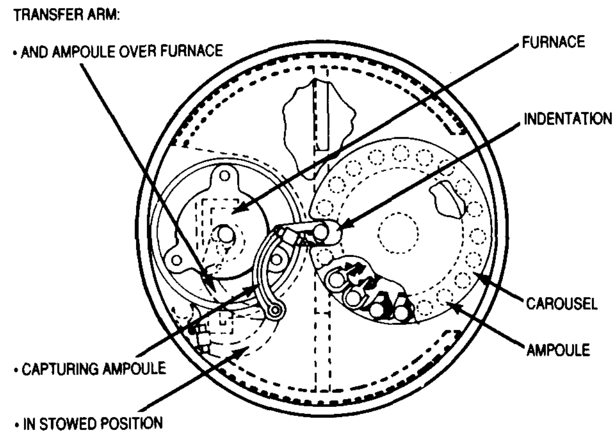
Integration Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Multiple Experiment Processing Furnace (MEPF)



MEPF Conceptual Design



MEPF Ampoule Transfer Concept

Importance

The MEPF will accommodate basic research studies and commercial applications that involve the solidification of metals and semiconductor materials. This improved, second-generation version of previous directional solidification furnaces will expand research and production possibilities by processing more and larger samples and permitting sample exchange on orbit. The furnace will be modular to accommodate a variety of experiment thermal requirements and allow rapid changeout of components between flights. Samples processed in the MEPF will be large enough to be tested for strength. Two MEPF concepts are being developed. One will be designed for the Spacelab habitable module, and one will fly on the Materials Science Laboratory (MSL).

Method

Each MEPF will be able to process up to 20 samples per mission, continuously melting and rapidly cooling each sample at a controlled rate. The apparatus will have the capability to provide a highly efficient rapid liquid and/or gaseous quench for the samples. As the furnace moves along the length of each sample, which remains stationary to reduce acceleration influences on the process, the sample will be subjected to a hot zone in which temperatures can reach 1,600 °C in one module (2,000 °C in the other), an insulating (adiabatic) zone that separates the hot and cold zones, and a gaseous helium cooling zone. The furnace translation rates will range from 0.01 to 100 millimeters per minute to accommodate the directional solidification process. The length of the adiabatic zone will be variable to accommodate various axial temperature gradients desired by the investigator for the sample being processed, and the furnace's rate of movement will be programmed for individual sample runs. The MEPF design also allows investigators on the ground to control experiments.

Carrier

MSL or Spacelab

Sample Summary

- Length: 14 cm
- Diameter: up to 4 cm
- Capacity/flight: 20 samples/flight

Physical Characteristics

Physical characteristics of the MEPF have not been finalized.

Operational Parameters

- Power: 1,150 W (peak); 800 W (nominal)
- Voltage: 28 ±4 Vdc
- Temperature
  - Heating zone: 600 to 1,600 °C/2,000 °C
  - Cooling zone: 50 to 600 °C (initial concept)
  - Booster heater: 600 to 1,600 °C
- Translation rate: 0.01 to 100 mm/min
- Heating rate: 600 °C/h (maximum); 60 °C/h (minimum)
- Quench rate: 100 °C/sec

Instrumentation

- 20-sample automatic carousel
- Sample thermocouples: 6 (minimum)
- Power distribution system
- Power controller and signal conditioner
- Gaseous helium cooling, quench, and sample cooldown system
- Gaseous helium/Freon heat exchanger

Data Acquisition

Data are acquired by the MEPF Data Acquisition System, which interfaces with the MSL or manned module System Control Unit, and may be recorded by the onboard Experiment Tape Recorder and/or downlinked for real-time analysis. A time history of the temperature profile within the sample during processing and housekeeping data are available to investigators.

Facility Integration

The MEPF is designed to be housed in an Experiment Apparatus Container and mounted on the MSL carrier in the payload bay or in the Spacelab module and ultimately in the Space Station.

- Special Interface Requirements: The MEPF will interface with the appropriate structural, power, command and data handling, and environmental control services offered to experiments; however, the MEPF will occupy two-thirds of the space designated for experiment hardware on the MSL and may require two-thirds of the power provided by that carrier.
- Integration Options: None

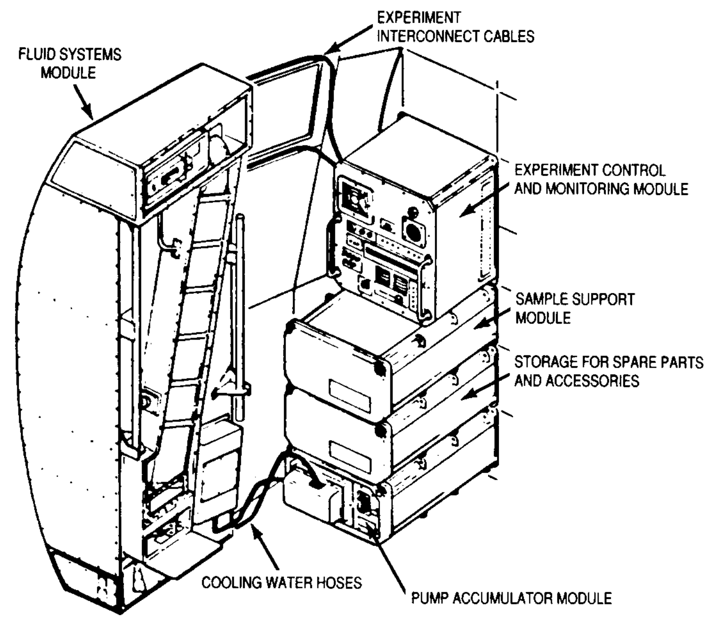
Additional Notes

The requirements definition for the MEPF has been completed, and the activities leading to the design and development of MEPF breadboards have started.

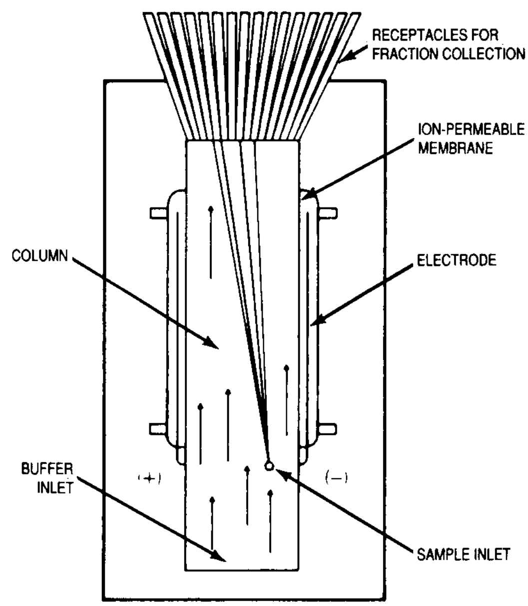
Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Continuous Flow Electrophoresis System (CFES)



Continuous Flow Electrophoresis System



Electrophoresis System

Importance

The CFES apparatus separates and purifies living cells and macro-molecules without the gravity-induced influences of thermal convection and sedimentation. When separated into ultra-pure forms, many cells and proteins are used to make improved medical and pharmaceutical products. Earth-based processing of these substances in large quantities is difficult and expensive because sedimentation and thermal convection cause the substances to mix together. Initial experiments with the CFES in microgravity, however, indicate that biological substances can be separated into pure forms and in large quantities in space; the CFES can separate over 400 times the quantity of material that can be separated in the same facility on the ground.

Method

In the CFES, the sample of biological material to be separated is injected into a buffer solution that flows through an electrical field in the electrophoretic chamber. Because the ingredients of the sample are of varying charges and sizes, the particles are deflected toward the electrode of the opposite charge; the degree of their lateral movement is determined by cell or molecule size. This deflection separates the sample stream into particle streams which then exit the chamber through different outlet ports where the separated materials are collected individually.

As the CFES apparatus has been refined, the flight configuration has changed. In the earlier designs, samples were maintained in a Sample Support Module (SSM), and all elements of the sample material were collected and returned to Earth, giving investigators a picture of what occurred throughout the separation column. In the current configuration, only the product of interest is collected and retained in the Fluid System Module (FSM); all other elements are treated as waste products. This design is a prototype for commercial applications. It processes one large sample for a longer period of time than the earlier design.

Carrier

Orbiter middeck

Sample Summary

- Capacity/flight: 1 sample
- Volume: 2 liters

Physical Characteristics

- CFES weight: 371.47 kg
- FSM
  - Dimensions (LxWxH): 76.2 cm x 65.0 cm x 201.7 cm
  - Weight: 223.4 kg
- SSM
  - Dimensions (LxWxH): 48.9 cm x 49.1 cm x 27.9 cm
  - Weight: 33.7 kg
  - Volume: 0.07 m^3

Operational Parameters

- Power: 684 W (maximum)
- Power profile
  - SSM (lift-off to landing): 84 W
  - CFES and SSM (operating): 684 W
- Voltage: 28 ±4 Vdc
- Temperature profile
  - Column temperature (operating): 12 to 16 °C gradient
  - SSM (lift-off to landing): 4 °C (nominal)

Instrumentation

Microcomputer (control and monitoring)

Data Acquisition

Data analysis is performed on the separated and collected materials. A Nikon F-2 camera is available to photograph the separation process.

Facility Integration

The Experiment Command and Monitoring Module and the SSM (used in early designs only) occupy middeck locker spaces on the forward avionics bulkhead. The FSM is mounted in the middeck galley location.

- Special Interface Requirements: The SSM must be located so that there is clearance on its left side for the thermoelectric cooling system. The Pump Accumulator Module is connected to the payload bay heat exchanger by way of interfaces located beneath the FSM.
- Integration Options: None

Additional Notes

The CFES apparatus has been flown on seven Shuttle missions; in exchange for the flights, NASA investigators have been able to process materials in the apparatus.

Development Center

The CFES apparatus is the result of a Joint Endeavor Agreement between the McDonnell Douglas Astronautics Company and the Marshall Space Flight Center.

McDonnell Douglas Astronautics Company
P.O. Box 516
St. Louis, MO 63166
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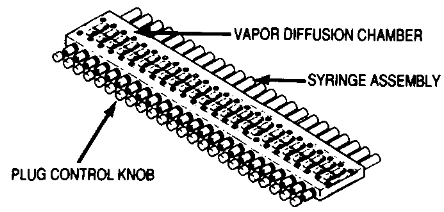
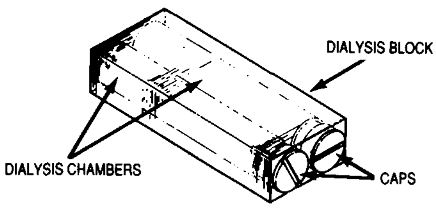
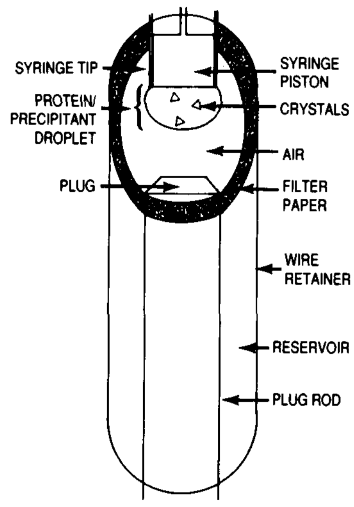
Hand-Held Protein Crystal Growth (HPCG) Experiment Apparatus



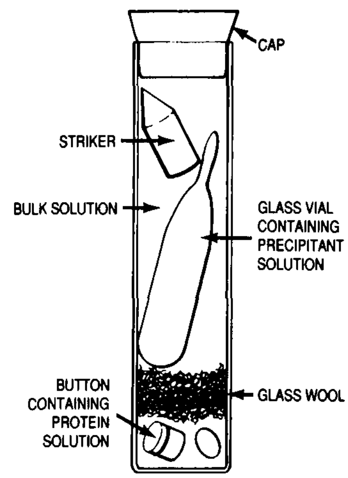
HPCG Vapor Diffusion Apparatus



HPCG Dialysis Apparatus



HPCG Vapor Diffusion Chamber



HPCG Dialysis Chamber

Importance

The HPCG apparatus is designed to explore the use of the microgravity environment for growing protein crystals that are of medical and scientific interest and is the forerunner of the Protein Crystal Growth (PCG) apparatus. Lessons learned about hardware design for efficient crystal growth in space have been applied to the development of the PCG hardware. HPCG experimentation also has important implications for enzyme engineering and the design of chemotherapeutic agents and pharmaceutical products. Through X-ray diffraction, the molecular structures of biological materials can be determined. Using the vapor diffusion and dialysis techniques available in the HPCG apparatus, investigators are able to organize biological molecules into large, single, symmetrical crystals. Since protein crystals grown in microgravity tend to be larger and to have fewer defects resulting from fluid disturbances than crystals grown on Earth, they should be easier to study and yield more information about molecular structures.

Method

The HPCG is composed of the Vapor Diffusion Apparatus (VDA) and the Dialysis Apparatus (DA). Experiments in the VDA take place in closed chambers that are covered with clear plastic windows for visual and photographic monitoring. A droplet of protein/precipitant solution is extruded onto the tip of a syringe and suspended over a reservoir of precipitant solution that is of higher concentration than the precipitant in the droplet. A difference in vapor pressure between the two concentrations causes water vapor to move from the droplet to the reservoir, and conditions within the drop become conducive to protein crystal growth. When crystallization is complete, the droplet containing the crystals is drawn back into the syringe. After return to Earth, the crystals are removed from the syringes and bombarded with X-rays to create diffraction patterns for computer analysis of their structures.

The DA experiments take place in a dialysis block filled with a buffer solution. Into this solution are placed several cups, or buttons, containing protein solutions, a thin-walled glass vial containing a highly concentrated precipitant solution, and a striker to break the vial. The protein solution is contained in each cup by a semi-permeable membrane. The experiment is activated when the vial is broken by shaking the dialysis block. The precipitating agent released from the vial causes a predetermined concentration of precipitant to exist in the buffer solution. The precipitating agent moves through the membrane into the cups as the two solutions move toward equilibrium. Within the cups, the protein solutions become more concentrated in precipitating agent, and protein crystallization begins. The dialysis block is returned intact for analysis.

Carrier

Orbiter middeck

Sample Summary

- Capacity/flight: 48 VDA and 12 DA experiments/flight
- Sample volume
  - –Protein solution: 100 microliters/chamber (maximum)
  - –Precipitant solution: 1 milliliter/chamber (minimum)

Physical Characteristics

- VDA
  - –Dimensions (LxWxH): 35.42 cm x 1.60 cm x 13.33 cm
  - –Weight: 0.86 kg
- DA
  - –Dimensions (LxWxH): 12.32 cm x 2.41 cm x 4.45 cm
  - –Weight: 0.19 kg (each)
- HPCG weight: 4.14 kg

Operational Parameters

- Temperature: Ambient middeck
- Pressure: 1 atm

Instrumentation

35-mm camera

Data Acquisition

A Nikon 35-mm camera takes color photographs of the VDA experiments at various times during the flight. Accessories include a 35-mm camera battery pack and a day/hour/minute time-tag; a Micro-Nikkor 55-mm, F-2.8 lens; a 27.5-mm Nikon lens extender; and a Nikon 52-mm polarizing filter.

Facility Integration

The HPCG is stowed in a modular stowage locker.

- Special Interface Requirements: Before activation of the VDAs, a bracket with two VDAs is attached to the left side of the locker with two thumb screws. This bracket is detached and restowed after deactivation.
- Integration Options: The VDA can also be attached to trays mounted within a Refrigerator/Incubator Module.

Additional Notes

The HPCG apparatus has been flown on four missions.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
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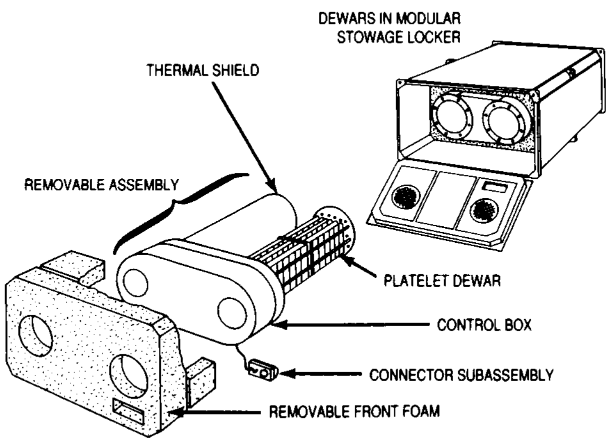
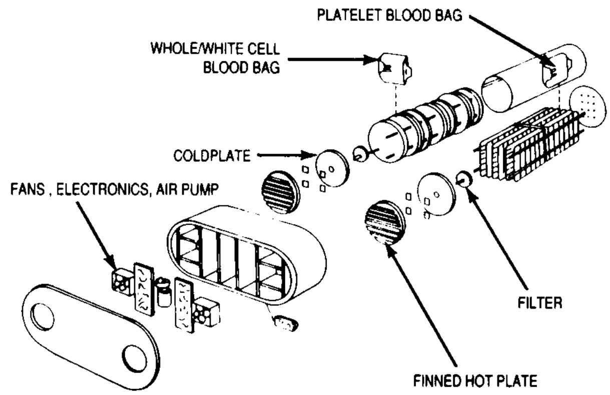
Initial Blood Storage Experiment (IBSE) Apparatus



Initial Blood Storage Experiment Apparatus



IBSE Module (Exploded View)

Importance

When blood is stored on Earth, cell-cell and cell-container wall interactions cause sedimentation lesions, which may be very harmful to blood elements. Sedimentation induced by gravity causes platelets to settle to the bottom of storage containers, and the blood begins to clot. Other blood components die as a result of sedimentation and release chemicals that negatively affect other blood cells. In microgravity, the various components of blood remain in suspension, since the effects of sedimentation are minimized.

The IBSE, a blood storage apparatus, is designed to investigate factors that limit the storage of human blood in space. It can be used to compare blood components stored in orbit with blood stored on Earth, studying changes in cell size, shape, metabolism, physiology, and immunologic function. The results of experimentation in the IBSE should improve blood storage techniques in space, improve understanding of basic blood cell physiology, and contribute to related ground-based research, particularly in the areas of improved survival and efficiency of blood elements for transfusion.

Method

Experiments conducted in the IBSE evaluate the fundamental cell physiology of erythrocytes, platelets, and leukocytes during storage in microgravity in three different polymer/plasticizer formulations. The IBSE module, consisting of two insulated containers (dewars) with storage racks and an electronic control box, is partially disassembled, and standard blood bags are placed on the storage racks. The racks are reinserted into the dewar, and the dewar lids are bolted into place. The module is then placed inside a middeck locker, using Pyrell foam to isolate the hardware from the sides of the locker. Power is applied through an electrical connector on a front panel of the door to maintain the specified temperature level and air exchange rate in each dewar. The locker can be transported to the orbiter approximately 12 hours before launch.

Carrier

Orbiter middeck

Sample Summary

- Cold dewar module: Contains two cold dewars that together hold six standard blood bags [three 250-ml bags (whole blood), three 75-ml bags (leukocytes)]
- Warm dewar module: Contains one warm dewar and one cold dewar, holding a total of ten 60-ml standard blood bags (platelets)

Physical Characteristics

- Dimensions (LxWxH): 44.6 cm x 39.2 cm x 18.4 cm
- Weight
  - Cold module: 24.3 kg
  - Warm module: 22.1 kg
- Dewar construction: Stainless steel

Operational Parameters

- Input power: 125 W
- Input voltage: 28 ±4 Vdc
- Temperature
  - Cold dewar: 5 ±1 °C
  - Warm dewar: 22 ±1 °C

Instrumentation

The electrical resistance of a thermistor mounted on the coldplate within each of the two dewars in a single locker can be measured by three independent female electrical connectors on the front panel of the locker. A green light-emitting diode on the same front panel is lit when 28-Vdc power is applied to the locker.

Data Acquisition

While the experiment is running, only internal dewar temperatures can be measured manually with a multimeter. Electrical current to the IBSE module can be monitored as an indication of the cooling margin of the thermoelectric devices.

Facility Integration

The IBSE apparatus fits inside a single modular stowage locker in the orbiter middeck.

- Special Interface Requirements: A modified locker door with an internal fan permits cabin air to flow over the blood bags and through the locker to cool the electrical equipment. The internal dewar temperature level can be modified by changing a resistor on a printed circuit card mounted inside the control box.
- Integration Options: None

Additional Notes

The IBSE first flew on Shuttle mission 61-C in January 1986.

Development Center

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Flight Projects Engineering Office
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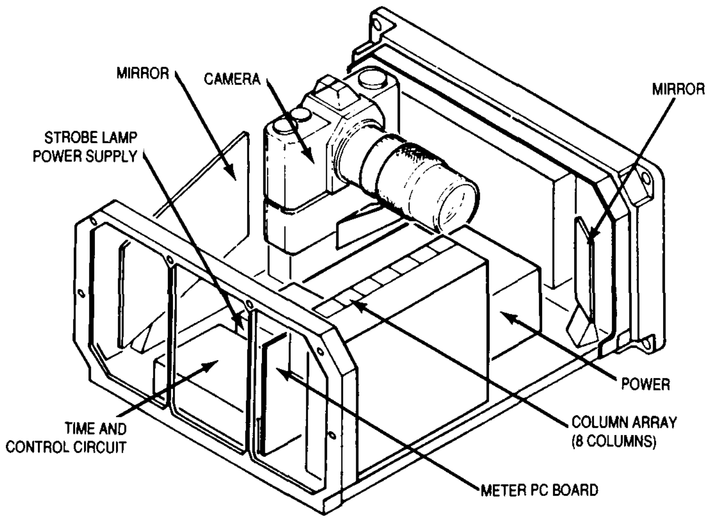
Isoelectric Focusing (IEF) Experiment Apparatus



Isoelectric Focusing Experiment Apparatus

Importance

The IEF apparatus is being used to determine the best experiment design for producing very pure separations of proteins, viruses, cells, and other biological materials in space. Isoelectric focusing is the most powerful electrophoretic technique for separating and purifying biological materials on a small scale. The extent of electroosmosis, or fluid convection, in isoelectric focusing is not known, however, because the ground-based techniques for eliminating density-dependent convection also eliminate electroosmosis. The IEF apparatus, therefore, has been designed for use in the microgravity environment of space to assess the role of electroosmosis in isoelectric focusing. Experiments conducted in the IEF apparatus will yield data that will be indispensable in developing an advanced design IEF device for commercial production of biological samples of great purity.

Method

In microgravity, density-dependent convection is minimized but electroosmosis still occurs. To produce a pH gradient in the ampholyte buffer and focus the particles to be separated, 70-Vdc power is applied simultaneously across (end to end) each of eight columns in the IEF apparatus. Movement of colored samples to their isoelectric points, the points at which the pH of the sample and the pH of the buffer are the same, is recorded photographically. Focused sample separations are harvested.

Carrier

Orbiter middeck

Sample Summary

- Capacity/flight: Eight IEF columns per experiment apparatus; two apparatus ready for flight
- Length: 5.08 cm
- Diameter: 0.64 cm
- Volume: 0.82 cm^3

Physical Characteristics

- IEF assembly
  - Dimensions (LxWxH): 53.34 cm x 48.26 cm x 22.86 cm
  - Weight: 28.70 kg
  - Volume: 0.07 m^3
- Column assemblies
  - Dimensions (LxWxH): 2.54 cm x 2.54 cm x 9.91 cm
  - Weight: Varies
  - Volume: 63.90 cm^3

Operational Parameters

• Power:	30 W (maximum), 7.3 W (minimum)
• Voltage	
- IEF assembly:	15 Vdc*
- Column assemblies:	70 Vdc
• Temperature:	Ambient middeck
• Sequence:	90 min

*Ten 1.5-Vdc alkaline "D" cells in a sealed battery box inside the container provide all power for the IEF apparatus.

Instrumentation

- 35-mm camera
- Light-emitting diode (LED) display of voltage and current
- Electronic control system

Data Acquisition

Data are acquired through 40 35-mm photographs. The first 10 pictures are taken at 3-minute intervals; the remaining 30 are taken at 2-minute intervals. Each picture includes the LED display.

Facility Integration

The IEF apparatus replaces a modular stowage locker. The experiment hardware is fastened to a single adapter plate, which, when integrated into the orbiter middeck, is fastened to the middeck wire trays.

- Special Interface Requirements: A location for the container should be selected in which adjacent apparatus will not cause the temperature of the IEF hardware to change from external sources.
- Integration Options: None

Additional Notes

The IEF apparatus flew on Shuttle mission 41-B and is currently scheduled for one more flight. To determine the most efficient experiment configuration, the separation columns had different combinations of three kinds of partitions, two kinds of buffers, and one kind of coating to minimize electroosmosis. The high-quality materials produced on the flight proved the effectiveness of the apparatus.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
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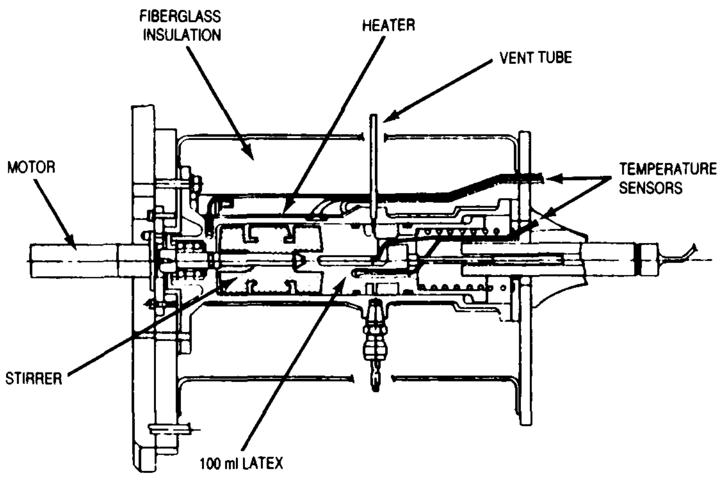
Monodisperse Latex Reactor System (MLRS)



Monodisperse Latex Reactor

Importance

The MLRS apparatus has produced large, highly uniform latex micro-spheres, the first commercial product manufactured in space. These spheres are used by industry and medicine in the calibration of sensitive scientific instruments and for other applications requiring extremely accurate measurements, such as membrane probes or carriers of drugs or biological specimens. In microgravity, sedimentation and buoyancy phenomena are minimized. Because a latex solution being processed in low gravity does not have to be stirred as vigorously to maintain suspension, the spheres do not coagulate, and the monodisperse qualities of the latex are maintained.

Method

The MLRS device consists of four latex reactors housed in an Experiment Apparatus Container (EAC), a Support Electronics Package (SEP), and two interconnecting cables (one for power, one for signal). Before flight, the reactors are filled with the latex material to be processed. After a crewmember turns on the MLRS apparatus, each of the reactors processes up to 100 ml of latex-forming material at two nominal temperatures (70 or 90 °C) or at other temperatures, if desired. The material can be stirred in the preprocess mode or stirred and heated in the process mode. After 20 hours, the experiment turns off automatically.

Carrier

Orbiter middeck

Sample Summary

- Volume per reactor: 25 to 30 g of latex in sufficient water to equal 100 ml
- Capacity: 4 reactors per EAC

Physical Characteristics

- MLRS
  - Weight: 71.27 kg
  - Volume: 0.13 m^3
- SEP with cables and adapter plate
  - Dimensions (LxWxH): 26.67 cm x 34.54 cm x 41.15 cm
  - Weight: 22.50 kg
  - Volume: 0.04 m^3
- Single reactor
  - Dimensions (L x dia.): 38.10 cm x 20.57 cm
  - Weight: 6.75 kg
  - Volume: 0.014 m^3

Operational Parameters

- Power
  - Preprocess mode: 75 W
  - Process mode: 382 W (maximum)
- Voltage
  - MLRS and SEP: 28 ±4 Vdc
  - Single Reactor: 36 Vdc
- Temperature (process mode): Ambient to 90 °C

Instrumentation

One volume change and four temperature probes per reactor

Data Acquisition

During the process mode, one volume and four temperatures (base, wall, piston, and fluid) are measured. The electronics system converts the acquired analog data to digital data and records up to 22 channels of data at a rate of one sample per second.

Facility Integration

The MLRS device is located in the space occupied by three modular stowage lockers. The EAC containing the MLRS apparatus uses a double adapter plate. The SEP is fastened to a single adapter plate, which is the interface between the SEP and orbiter.

- Special Interface Requirements: None
- Integration Options: None

Additional Notes

The MLRS has been flown on five missions and is currently scheduled for three more flights. The 10-micrometer spheres are marketed currently by the National Bureau of Standards (NBS) as Standard Reference Material (SRM) #1960 for $608.00 per vial; the 30-micrometer spheres are marketed by NBS as SRM #1961 for $608.00 per vial. A microscope slide of the 10-micrometer spheres is now available for microscope calibration and sells as SRM #1965 for $77.00 per slide.

Development Center

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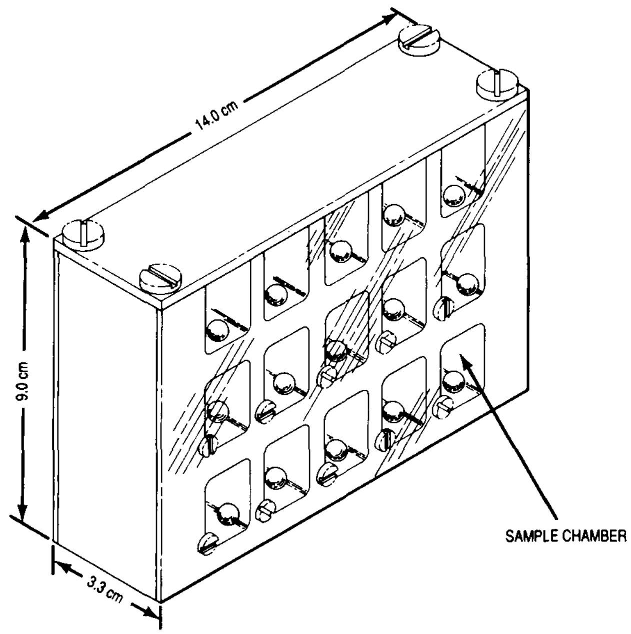
Phase Partitioning Experiment (PPE) Apparatus



Phase Partitioning Experiment Apparatus

Importance

The PPE apparatus measures the spontaneous demixing of liquid-liquid, aqueous polymer two-phase systems in microgravity. Two-phase separation is a method widely used in industry and in research to separate biological cells and proteins. Experiments conducted in this apparatus study the effects of altering volume ratios, viscosity, interfacial tension, interfacial bulk phase potential, and phase composition on the kinetics of demixing and the final disposition of the phases. Additionally, the PPE apparatus explores the effects of chamber geometry, materials, and wall coatings on the above parameters. Finally, the PPE device allows model bioprocessing experiments to be carried out using glutaraldehyde hardened cells. The results are of interest to biophysicists as well as scientists concerned with the general demixing behavior of liquid-liquid, two-phase systems, such as alloys, in microgravity.

Method

The PPE apparatus is configured to study two methods of phase separation (natural coalescence and surface tension) and to allow variations in interfacial tension, phase volume ratio, phase system composition, and added particles. The Plexiglas PPE apparatus has 15 to 24 cavities filled with small quantities of two different polymers in simple water/salt solutions. The mixtures have different volume fractions, viscosities, and interface potentials. The experiment apparatus is shaken vigorously and photographed to record phase separation. Half of the experiments are performed in chambers milled in the Plexiglas, the other half in glass cuvettes which fit into Plexiglas containers.

Carrier

Orbiter middeck

Sample Summary

- Capacity/flight: 24 experiments per PPE apparatus
- Sample chamber (LxWxH): typically 1.4 cm x 1.4 cm x 1.4 cm

Physical Characteristics

- Dimensions (LxWxH): 14.0 cm x 3.3 cm x approximately 9.0 cm
- Weight: 0.7 kg
- Volume: 526.7 cm^3

Operational Parameters

- Experiment duration: 2 h
- Temperature: Ambient middeck
- Operator time: Approximately 45 min

Instrumentation

- 35-mm camera with hour/minute/second time-tag
- A liquid crystal thermometer is built into the PPE in a location from which it will appear in each data acquisition photograph.

Data Acquisition

Color prints are taken of the PPE at various times with a 35-mm Nikon camera, which has an hour/minute/second time-tag and a 35- to 70-mm Nikon zoom lens. On return to Earth, the data are analyzed by computer-enhanced feature analysis that shows final phase disposition and demixing-versus-time kinetic information. The camera lens and light box required for the experiment are always flown with the PPE.

Facility Integration

The PPE apparatus is stowed in a modular stowage locker.

- Special Interface Requirements: None; the PPE is self-contained.
- Integration Options: The PPE can be stowed in either a large or a small tray.

Additional Notes

The PPE has been flown on Shuttle missions 51-D (15 chambers) and 51-L (24 chambers) and is being considered for four more flights. For safety, liquids are contained in 5- to 10-mm thick Plexiglas. In some cases, the liquids are also contained in glass cuvettes. On future flights, Plexiglas may be replaced with Lexan or Margard.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
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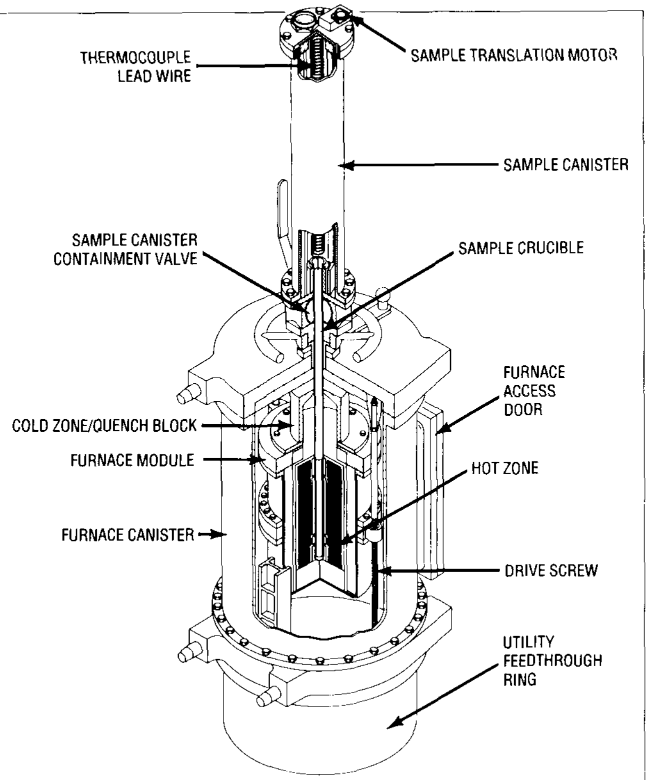
Metals and Alloys Solidification Apparatus (MASA)



Metals and Alloys Solidification Apparatus

Importance

The MASA will accommodate basic research studies and commercial applications that involve the solidification of metals. This improved, second-generation version of previous directional solidification furnaces will expand research and production possibilities by processing more and larger samples and permitting sample exchange on orbit. The furnace will be modular to accommodate a variety of experiment thermal requirements and allow rapid changeout of components between flights. Samples processed in the MASA will be large enough to be tested for strength.

Method

The MASA will be able to process up to 20 samples per mission, melting and rapidly cooling each sample at a controlled rate. The apparatus will have the capability to provide a highly efficient rapid liquid quench for the samples. As the furnace moves along the length of each sample, which remains stationary to reduce acceleration influences on the process, the sample will be subjected to a hot zone in which temperatures can reach 1,600 °C, an insulating (adiabatic) zone that separates the hot and cold zones, and a quench block for controlled cooling. The furnace translation rates will range from 0.24 to 3,600 millimeters per hour to accommodate the directional solidification process. The length of the adiabatic zone will be variable to accommodate various axial temperature gradients desired by the investigator for the sample being processed, and the furnace's rate of movement will be programmed for individual sample runs. The MASA design also allows investigators on the ground to control experiments.

Carrier

Spacelab

Sample Summary

• Length:	18 cm
• Diameter:	2 cm
• Capacity/flight:	20 samples/flight

Physical Characteristics

Physical characteristics of the MASA have not been finalized.

Operational Parameters

• Power:	1,150 W (peak); 800 W (nominal)
• Voltage:	28 ±4 Vdc
• Temperature	
- Hot zone:	300 to 1,600 °C
- Cold zone:	50 °C (or not to exceed 15% of the hot-zone temperature)
- Booster heater:	200 to 1,700 °C
• Translation rate:	0.24 to 3,600 mm/h
• Heating rate:	1,200 °C/h (maximum); 60 °C/h (minimum)
• Quench rate:	100 °C/sec

Instrumentation

- Sample thermocouples: 6 (minimum)
- Power distribution system
- Power controller and signal conditioner
- Gaseous helium and water quench and sample cooldown system

Data Acquisition

Data are acquired by the MASA System Control Unit, which interfaces with the Spacelab, and may be recorded by the onboard Experiment Tape Recorder and/or downlinked for real-time analysis. A time history of the temperature profile within the sample during processing and housekeeping data are available to investigators.

Facility Integration

The MASA is designed to be mounted in the Spacelab module and ultimately in the space station.

- Special Interface Requirements: The MASA will interface with the appropriate Spacelab structural, power, command and data handling, and environmental control services offered to experiments.
- Integration Options: None

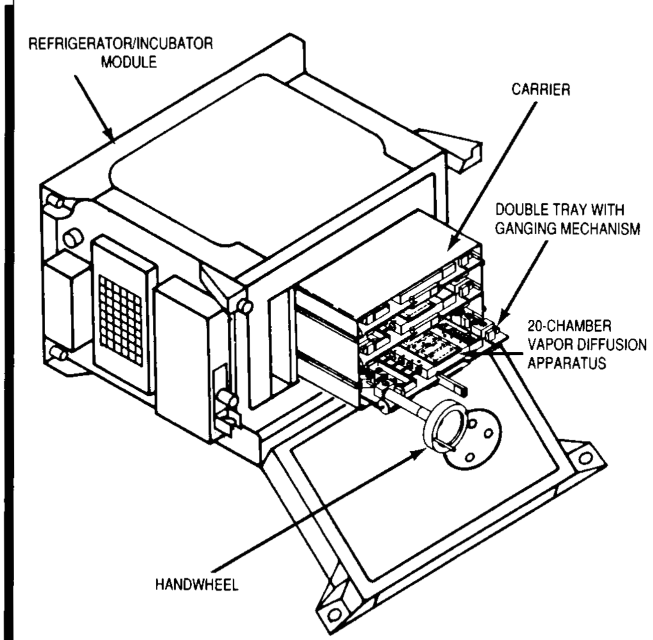
Additional Notes

The requirements definition for the MASA has been completed, and the activities leading to the design and development of the MASA prototype have started.

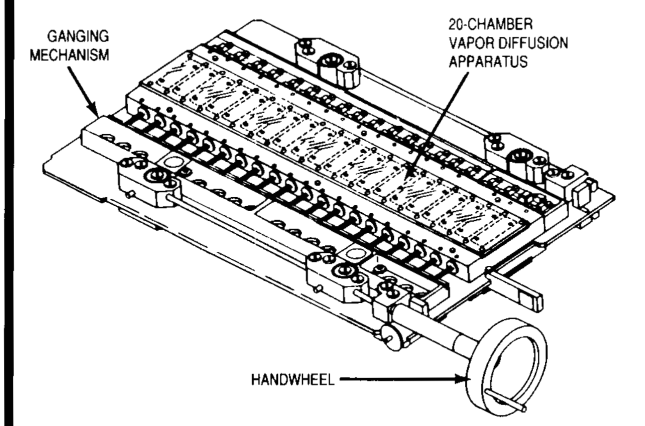
Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
Marshall Space Flight Center, AL 35812
(205) 544-1966

Protein Crystal Growth (PCG) Experiment Apparatus



PCG Flight Hardware



Vapor Diffusion Apparatus Tray

Importance

Experimentation in the PCG apparatus will evaluate the effects of gravity on the growth of protein crystals. Because the functions of biological materials are determined by their molecular structures, understanding of the complex functions and interrelationships among these proteins is advanced by X-ray diffraction of protein crystals to reveal their three-dimensional structures. Protein crystals grown in PCG experiments, because of their potential size, degree of purity, and quality, are highly valued for crystallographic analyses. The knowledge gained from analyses of these crystals through X-ray diffraction is of particular interest to the pharmaceutical and chemical industries for rational design of drugs, protein engineering, and other biotechnologies.

Method

The current design of the PCG hardware includes a PCG carrier assembly that accommodates three trays, each of which holds one Vapor Diffusion Apparatus (VDA). Each VDA contains 20 PCG experiments, which are activated simultaneously. The PCG carrier assembly fits in a Refrigerator/Incubator Module (R/IM) that allows control of the experiment temperature, which is monitored throughout. A 35-mm camera provides periodic still photographs of the in-flight process.

In each experiment chamber, a protein solution and a precipitant solution are held in two separate barrels of a syringe until on-orbit mixing of the solutions is initiated by a crewmember. At this point, the solutions are extruded to form a single drop on the tip of the syringe. The drop is suspended over a reservoir containing precipitant solution of a higher concentration. The difference in vapor pressures of the two solutions causes water vapor to transfer from the droplet to the reservoir, thus increasing the concentration of precipitant and protein in the drop. As the two solutions move toward equilibrium, conditions in the droplet become more suitable for the growth of protein crystals. After a predetermined growth period, a crewmember retracts the droplet into the syringe and can choose either to plug the syringe or to leave the syringe unplugged to preserve any crystals that might be destroyed by plugging. The crystals are returned to Earth for analysis.

Carrier

Orbiter middeck

Sample Summary

- PCG assembly capacity: Up to 60 experiments/flight
- Droplet size: Up to 80 microliters
- Precipitant reservoir solution: 1 milliliter (minimum)

Physical Characteristics

Data are given for the R/IM.

- Dimensions (LxWxH): 49.8 cm x 55.0 cm x 28.4 cm
- Weight: 31 kg

Operational Parameters

Data are given for the R/IM, which controls PCG experiment temperature.

- Power: 110 W (100% duty cycle)
- Voltage: 28 ±4 Vdc
- Temperature control
  - Control setpoint: 0 to 40 °C (manually adjustable)
  - Ambient range: 0 to 50 °C

Instrumentation

- 35-mm camera
- On/off power switch

Data Acquisition

Selected 35-mm close-up photographs are made of PCG experiments, using back lighting and cross polarization, which can enhance protein crystal images. Evaluation and characterization of protein crystals are completed by the investigators as soon as possible after flight.

Facility Integration

The R/IM, which houses the PCG apparatus, mounts in place of a standard modular stowage locker on the middeck forward bulkhead.

- Special Interface Requirements: The R/IM must be mounted in a left-hand locker location for the proper operation of its fan.
- Integration Option: The R/IM can be mounted in place of an orbiter middeck locker or in a Spacelab middeck experiment location.

Additional Notes

The PCG flight hardware housed 60 experiments, which included 11 different proteins, during the STS-26 mission in September 1988. Three R/IMs have been fabricated for use with the apparatus. The Hand-held Protein Crystal Growth (HPCG) apparatus, flown on four Shuttle flights, is the forerunner of the current PCG hardware design. The HPCG apparatus was important in the development of techniques for growing protein crystals in space.

Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
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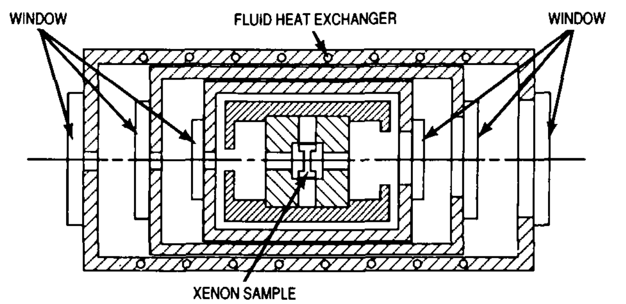
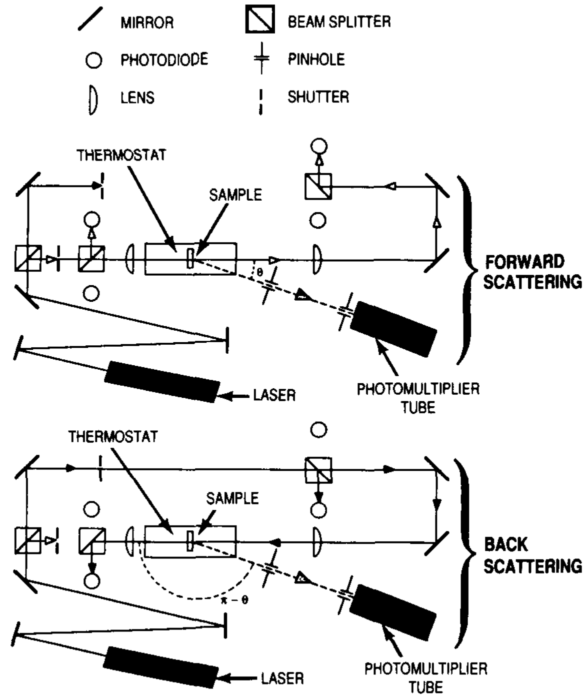
Critical Fluid Light Scattering Experiment (CFLSE) Apparatus



Critical Fluid Light Scattering Experiment Thermostat and Sample Cell



CFLSE Optical Layouts

Importance

The highest temperature at which a gas can be liquified by pressure alone is called the critical temperature. Near the critical temperature, a fluid exhibits many interesting physical characteristics which have been described theoretically in recent years but which are difficult to observe experimentally on Earth because of the significant density gradient induced by normal gravity and the divergence of compressibility as the critical temperature is approached. The theoretical predictions for these phenomena, therefore, cannot be adequately tested.

The purpose of the CFLSE apparatus is to measure the decay rates and correlation lengths of critical density fluctuations in xenon, a nearly ideal model fluid, very near its liquid-vapor critical point using laser light scattering and photon correlation spectroscopy. In low-gravity, the proposed light scattering measurements will be made at temperatures within 100 microKelvin of critical temperature and will provide the high-quality data required for detailed analysis in the field of fundamental physics of critical fluids. These data will provide a challenging test for existing generalized hydrodynamics theories of transport coefficients in the critical region.

Method

The CFLSE requires very precise optical alignment, light measurement, microKelvin temperature control, and submilli-g vibration isolation. The experiment measures the scattering intensity fluctuation correlation decay rate at two angles for each temperature while simultaneously recording the sample turbidity. The intensity and turbidity data are used to measure the correlation range at each temperature and to locate the critical temperature. Temperatures will cover (approximately) the range of 1 Kelvin to 100 microKelvin from the critical point. The fully automated system will permit continuous operation of the experiment for nominally 100 hours of data collection and will have the capability to discard data perturbed by extraneous, large accelerations.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

• Sample:	Xenon at approximately 57.6 atm
• Capacity/flight:	1 sample, multiple temperatures
• Path length:	100 micrometers
• Volume:	2 cm^3
• Viewing height (nominal):	100 micrometers

Physical Characteristics

• Dimensions (LxWxH)	
- Optics:	0.90 m x 0.60 m x 0.45 m
- Electronics:	0.3 m x 0.6 m x 0.6 m
• Volume	
- Optics:	0.27 m^3
- Electronics:	0.12 m^3
• Weight	
- Optics:	90 kg
- Electronics:	67.5 kg
- CFLSE instrument:	90 kg

Operational Parameters

• Power:	400 W (maximum) for 150 h
• Voltage:	28 Vdc
• Temperature	
- Sample:	Near 17 °C
- Ambient:	±1 °C at a temperature below 17 °C
• Experiment duration:	100 h (nominal)

Instrumentation

- Energy stabilized laser light source (HeNe)
- Low-noise photomultiplier detector
- Photocell detectors
- Beam switching shutters
- Accelerometer
- MicroKelvin thermostat assembly
- 144-channel correlator

Data Acquisition

Temperature, correlation function, turbidity, and selected housekeeping data will be acquired by a high-speed processor.

Facility Integration

The CFLSE apparatus is designed for integration on the MSL in the orbiter payload bay.

- Special Interface Requirements: The CFLSE apparatus will interface with standard MSL structural, power, communications, data handling, and environmental control services.
- Integration Options: None

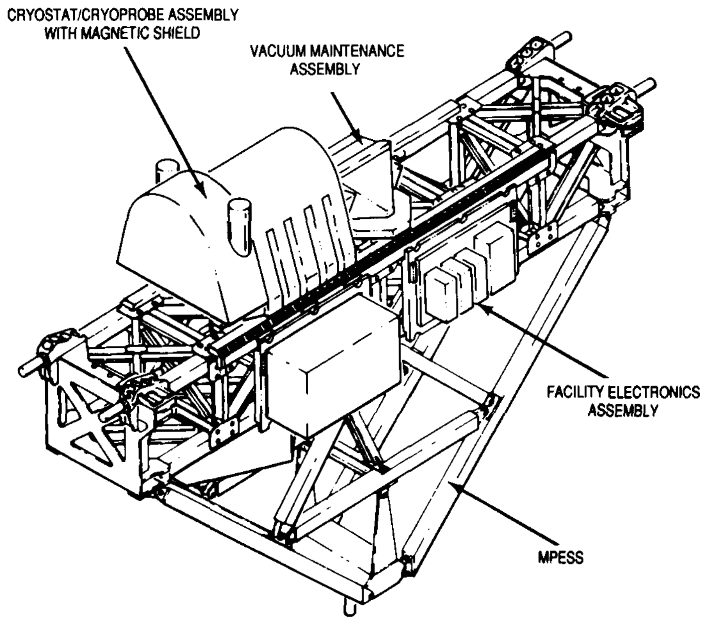
Additional Notes

The CFLSE apparatus is being developed by the University of Maryland under contract to Lewis Research Center.

Development Center

NASA/Lewis Research Center
Space Experiments Division
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-2864

Low-Temperature Research Facility (LTRF)



Low-Temperature Research Facility

Importance

The LTRF provides an opportunity for investigators of low-temperature phenomena to conduct experiments in the microgravity environment accessed by the Space Shuttle and, eventually, by the Space Station. The LTRF is particularly useful to experiments that require temperatures as low as 1.5 K and acceleration forces less than 10^{-4} g.

During the first flight of this facility, low-temperature fluid physics experiments investigating the bulk properties of superfluid helium were conducted. On its second flight, the facility will carry an experiment investigating the behavior of superfluid helium at the Lambda transition. This experiment will provide an important test of the theories of cooperative phase transitions.

Method

A cryostat in the LTRF accommodates up to 31.50 kg of instrumentation inside a volume filled with enough superfluid helium for a 1-week lifetime on orbit. A test sample mounted on a flange is immersed directly in the 1.5-K helium bath. Normally, the sample is cooled to 4.2 K several days to a few weeks before launch and is cooled to superfluid temperatures (less than 2.17 K) a few days before launch. The exact mode can be varied to meet user requirements. The external magnetic field is minimized by a magnetic shield that surrounds the entire cryostat. The LTRF also can be used in conjunction with a Space Acceleration Measurement System (SAMS) accelerometer, which will monitor the local acceleration environment.

An experiment in the LTRF may be preprogrammed and automated or monitored in real time on the ground. In the latter mode, investigators can command changes in experiment parameters as required.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

• Diameter:	20.32 cm (maximum)
• Length:	73.66 cm (maximum)
• Weight:	31.50 kg (maximum)
• Heat dissipation:	100 mW (nominal)*

*Larger heat loads are permissible but will reduce the operating lifetime of the LTRF.

Physical Characteristics

- Dimensions (LxWxH)
  - Cryostat: 121.92 cm x 60.96 cm x 60.96 cm
  - Magnetic shield: 137.16 cm x 102.87 cm x 86.36 cm
  - Vacuum maintenance assembly: 81.28 cm x 60.96 cm x 55.88 cm
  - Facility electronics assembly: 45.72 cm x 40.64 cm x 20.32 cm
- Volume of superfluid helium: 120 liters
- Weight
  - Cryostat: 153 kg (including cryogen and supports; no sample)
  - Magnetic shield: 101.25 kg
  - Vacuum maintenance assembly: 106.2 kg
  - Facility electronics assembly: 16.2 kg

Operational Parameters

- Voltage: 28 Vdc (Shuttle raw power)
- Power: 175 W
- Temperature
  - Sample: 1.5 to 4.5 K
  - LTRF: -20 °C to +40 °C (operating)
- Lifetime: 168 h on orbit

Instrumentation

- Temperature sensors
- Pressure sensors
- SAMS accelerometer (optional)
- Data system interface (RS 422)

Data Acquisition

The LTRF electronic interface to the MSL System Control Unit can provide both onboard recording and/or transmission of experiment data in real time.

Facility Integration

The LTRF has an established interface with the MSL. The cryostat and vacuum maintenance assembly are located on the top of the Mission-Peculiar Equipment Support Structure (MPESS); the supporting electronics are installed on the forward bulkhead of the MPESS, using MSL-provided coldplates.

- Special Interface Requirements: None
- Integration Options: With modifications to the data system, the LTRF can be integrated on a Spacelab pallet.

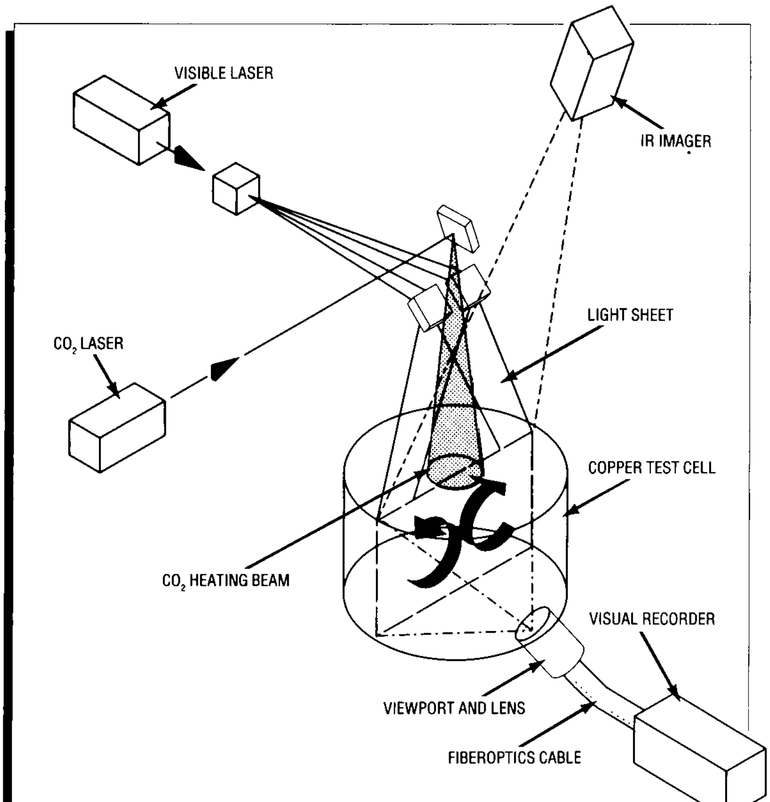
Additional Notes

The LTRF flew on a pallet during the Spacelab 2 mission, 51-F, in July 1985. Its next flight will be on an MSL.

Development Center

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-6336

Surface Tension Driven Convection Experiment (STDCE) Apparatus



Surface Tension Driven Convection Experiment Concept

Importance

Experiments conducted in the STDCE apparatus are designed to investigate both transient and steady-state thermocapillary flows in fluids; these flows result from the variations of surface tension with surface temperature. Oscillations in the velocity of thermocapillary flows may have deleterious effects on materials processing in space, particularly on solidification, crystal growth, and containerless processing. Adequate mathematical modeling of these flows and oscillations in velocity has not been possible on Earth because of an inability to isolate the phenomena affecting the flow, such as the thermal signature and the surface deformation. The data that can be obtained during extended experimentation in microgravity will better define these influences and allow investigators to complete the numerical model, leading to improved crystal growth and solidification processing techniques in space.

Method

In the STDCE apparatus, a circular container is filled with silicone oil, which is used as the model fluid. In one configuration, the free surface of the oil is heated centrally from above. In the second configuration, conductive heating of the oil volume in the chamber with a submerged cartridge produces temperature differences that are more likely to create oscillations. In each configuration, the oil volume can be selected to give either a flat or a curved free surface. Seven constant heat flux tests and five constant temperature differences are planned.

A cross section of the container will be illuminated by a sheet of light. Thermocapillary flows will be measured by recording the movement of light-scattering aluminum oxide particles mixed in the oil. Surface temperatures will be measured by a scanning infrared imager. The subsequent correlation of velocity distribution with surface temperature distribution will allow scientists to complete mathematical modeling.

Carrier

Spacelab

Sample Summary

- Sample liquid: 10 cs silicone oil
- Volume: 400 ml with adequate concentration of tracer particles
- Initial temperature: 25 °C

Physical Characteristics

- Test chamber dimensions (H x dia.): 5 cm x 10 cm
- Experiment and structure weight: 227 kg
- Support structure weight: 90 kg
- The electronics package and experiment hardware occupy a full Spacelab single rack.

Operational Parameters

- Power: 400 W (average)
- Power profile
  - Constant flux heating: 0.5 W (60 min: thermal equilibrium) 0.2 to 3.0 W (10 min: velocity equilibrium) (heating zone: 5 to 30 mm, flat and curved surfaces)
  - Constant temperature heating: 1.5 W (60 min: thermal equilibrium) 1.5 to 32.8 W (10 min: velocity equilibrium) (cartridge heating, flat and curved surfaces)
- Temperature differences: 10 to 65 °C
- Total duration: 5 h

Instrumentation

- Video camera
- Infrared imager
- Thermistors
- The STDCE uses the two Spacelab video cassette recorders to record the imager and video camera outputs.

Data Acquisition

The data acquisition and control system for the STDCE apparatus, which is in a developmental stage, will have the capabilities to record surface and bulk temperatures and flow velocity and to monitor and control the filling process and experiment cycles for postflight processing.

Facility Integration

Spacelab integration requirements for the STDCE apparatus are being investigated.

- Special Interface Requirements: As yet undetermined
- Integration Options: As yet undetermined

Additional Notes

The science requirements of the STDCE have been expanded to obtain additional data during the initial flight and a reflight. The planned completion date for the reconfigured experiment hardware is March 1990.

Development Center

NASA/Lewis Research Center
Space Experiments Division
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Cleveland, OH 44135
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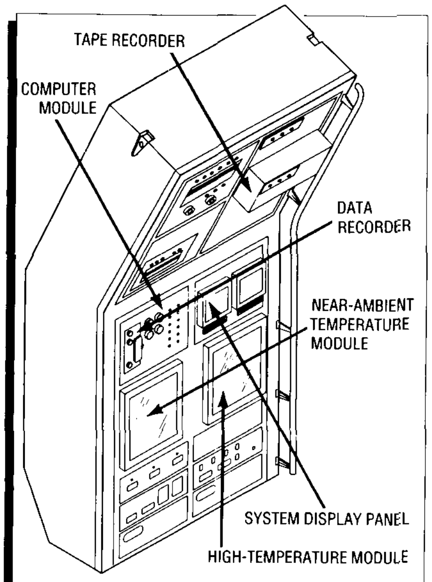
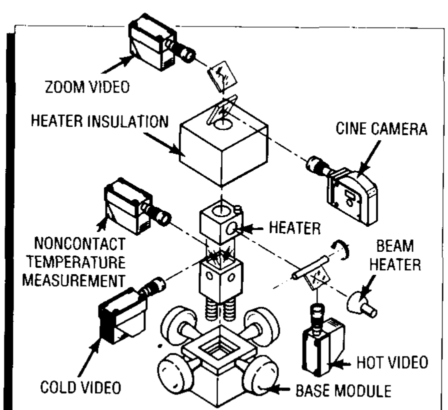
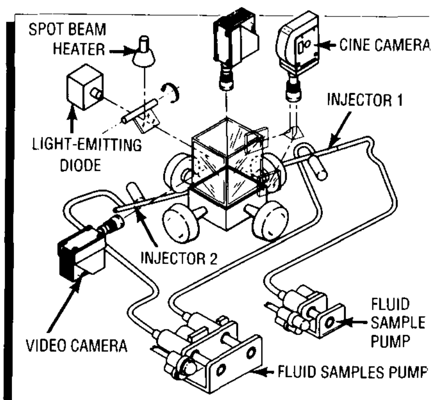
Drop Physics Module (DPM)



Drop Physics Module



High-Temperature Dual-Zone Chamber



Near-Ambient Chamber

Importance

The DPM will be a multipurpose acoustic positioning device, designed to accommodate ambient- and elevated-temperature (around 1000 °C) experiments. Isolation from containers or other mechanical holding materials enhances the ability to undercool a sample, allows the study of highly reactive materials, minimizes specimen contamination, and reveals the subtle interaction between capillary and thermo-inertial forces. The DPM is the first of a series of modules being developed for an integrated containerless processing facility for the space station.

Method

Two acoustic positioning chamber bays will provide the capability to carry out independent near-ambient and high-temperature investigations. Several sealed chambers will accommodate different processing environments. Experimenters will be able to control temperature, hydrostatic pressure, composition of the host gas, humidity, lighting, and acoustic positioning force. Liquid samples will be injected into the near-ambient chamber and accurately positioned with acoustic forces. Sample rotation, positional and shape oscillation, and translation within the processing chamber will be induced when necessary. Liquid behavior and shape will be recorded through video and cinefilm camera systems. Solid samples will be deployed into the cool zone of the dual-temperature experiment cell, translated into the hot zone for processing, and moved back into the cool zone for faster cooling. High sample temperatures will be attained by both resistance and beam heating.

Carrier

Spacelab

Sample Summary

• Samples:	Liquid drops, liquid shells, solid samples
• Diameter:	0.5- to 2.7-cm drops (near-ambient chamber); 0.5- to 1-cm melts (high-temperature chamber)
• Temperature range:	Ambient to 100 °C (near-ambient chamber); ambient to 800 °C (resistive furnace); above 800 °C (beam heater)

Physical Characteristics

- Near-ambient chamber: 15.25 cm x 15.25 cm x 30 cm
- High-temperature cell: 6.35 cm x 6.35 cm x 30.5 cm
- The DPM fits inside a Spacelab double rack.

Operational Parameters

- Video imaging
  - 30 frames/sec RS-170 format with 1/60- and 1/500-sec shuttering
  - Resolution: 20 μ with 7.5-mm field of view (FOV) to 200 μ with 78-mm FOV
- Cinefilm imaging
  - 16-mm monochrome or color
  - Variable frame rate: 10 to 400 frames/sec
- Infrared (IR) thermal imaging
  - Spectral response: 0.4 to 5 μ
  - Frame rate: 10/sec (minimum)
- Thermocouple measurements
  - Fixed wall thermocouples: ±1-°C accuracy
  - Varying position probe: ±5-°C accuracy
- Acoustic drive
  - Carrier frequencies: 1 to 8 kHz
  - Force modulation: 1 to 30 Hz (minimum)
  - Sound pressure level: 130 to 155 dB (re 0.0002 μBar)
  - Torque: 1.0 dyne/cm (maximum) at ambient temperature
- Beam heater
  - Lamp color temperature: 2500 K
  - Power: 250 W with 1.25-cm beam diameter
- Peak power: 1.8 kW

Instrumentation

- Cathode ray tube and system parameter display panels
- Hydrostatic pressure, humidity, and temperature sensors
- Sheet lighting illumination
- Video and cinefilm camera systems
- IR thermal imager
- Acoustic microphones
- Process Control and Data Acquisition (PCDA) microprocessor

Data Acquisition

PCDA microprocessor controls all automatic functions and records engineering data. Video data are either recorded on the DPM high data rate recorder or on Spacelab/orbiter recorders or downlinked through the Spacelab video analog switch. Cinefilm data are recorded on 16-mm, 400- and 1200-ft magazines. Unused electrical interfaces for power and data acquisition ports will be made available for additional experiment-peculiar instruments.

Facility Integration

The DPM is integrated in a Spacelab double rack, which will accommodate some special stowage items. Other special hardware items will be stored in Spacelab stowage.

- Special Interface Requirements: Avionic air cooling is required in addition to the standard power and mechanical interfaces.
- Integration Options: None

Additional Notes

The DPM design has been influenced by those of previous flight instruments: the Drop Dynamics Module, the Three-Axis Acoustic Levitator, and the Acoustic Containerless Experiment System.

Development Center

NASA/Jet Propulsion Laboratory
Modular Containerless Processing Facility Project
4800 Oak Grove Drive
Pasadena, CA 91109
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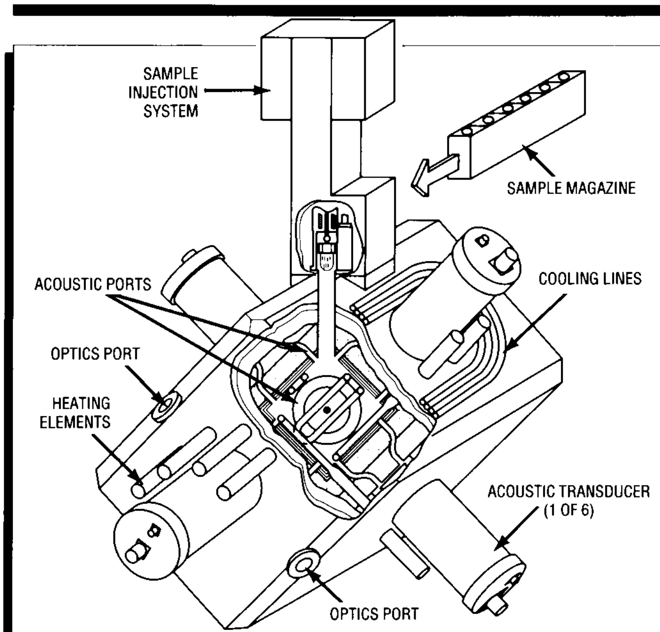
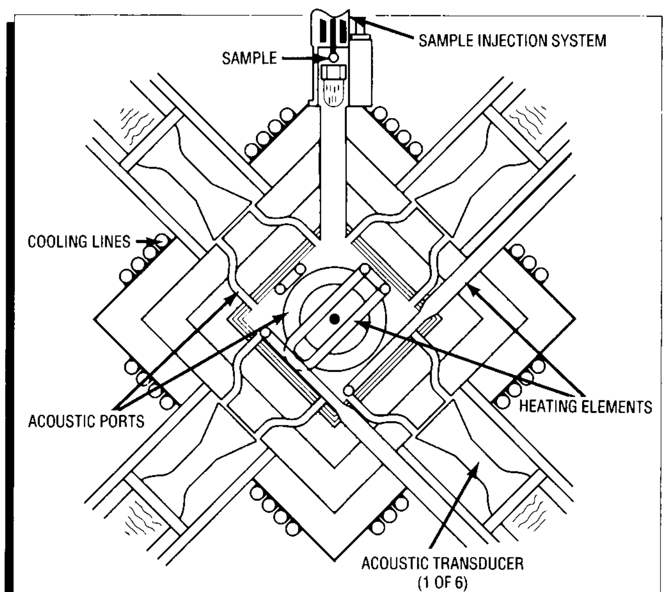
Acoustic Levitation Furnace (ALF)



Acoustic Levitation Furnace Processing Module (cutaway view)



ALF Processing Module (cross section)

Importance

Materials that must be processed at high temperatures can be contaminated if the containers in which they are processed are also transformed by such temperatures. Because contamination reduces the efficiency of glasses and ceramics, containerless processing techniques are particularly valued by the optics and electrical industries. In microgravity, sound waves can be used to levitate a sample for long periods of time at high temperatures so that a processing container is not needed and contamination of the sample is eliminated.

The ALF will be a containerless processing hot-wall furnace for producing very pure materials and for melting and undercooling studies of high-temperature glasses, ceramics, metals, and alloys in microgravity. Its acoustic levitation system will be able to position the sample with improved stability to maintain the containerless condition. The facility will accommodate a large number of spherical samples and will be applicable to a variety of experiment programs.

Method

The ALF will consist of a 1750-°C, hot-wall furnace and an acoustic levitation system. The sound pressure will be adjusted electronically by computer and can be used to change the molten sample shape to study fluid dynamics or to measure physical properties, such as surface tension and viscosity. By properly phasing the acoustic signal to two axes, the ALF can produce spin in the sample.

The ALF will provide noncontact, user-calibrated temperature measurement capabilities and thermal imaging of the specimen at several optical wavelengths. During all stages of processing, two orthogonal views of the specimen will be recorded on video. Samples may be processed in air, argon, nitrogen, or mixtures of these gases. The sample environment will have active and passive gaseous and particulate contamination control measures. Occasional venting to space of moderate quantities of nonhazardous gases is anticipated.

Carrier

Spacelab

Sample Summary

• Shape:	Spherical
• Diameter:	2 to 6 mm
• Capacity/flight:	6 samples/cartridge; number of samples limited by length of mission and shared resources

Physical Characteristics

The ALF will be designed to fit within a standard Spacelab double rack and will be accessible from the front for calibration, servicing, repair, and replacement.

Operational Parameters

- Power: Approximately 2.0 kW
- Voltage: 28 ±4 Vdc; 400 Hz, 115 Vac
- Furnace temperature: 1750 °C (maximum)
- Isothermality: 5 °C/cm
- Temperature control: ±3 °C
- Heat rate: 2 °C/sec (minimum)
- Cooling rate: 1 °C/sec (minimum)
- Quench rate (gas): Up to 20 °C/sec
- Sample spin: Controlled for low or no spin
- Sample levitation: Variable acoustic field
- Sample environment: Low contamination; nitrogen, argon, oxygen mixture

Instrumentation

- General housekeeping parameters
- Acoustic controller (frequency, sound, phase)
- Furnace controller (current, temperature)
- Power (current, voltage)
- Pressure measurements
- Time sources monitors
- Sample illumination
- Sample measurements
  - Pyrometry: single spot and thermal imaging
  - Silhouette
  - Rotation
  - Recalescence
  - Video and film camera pictures
  - Spin
  - Shape
  - Position
  - Viscosity
  - Surface tension
- Low-g (10^{-5}) 3-axis data

Data Acquisition

- Low-rate data
  - Analog: 0 to 5 V
  - Discrete: 0 or 5 V
  - Typical acquisition rate: 1 sample/sec
- High-rate data
  - Analog: 0 to 5 V
  - Typical acquisition rate: less than 16 Mbyte/sec
- Video data of sample (two views)
- Film recording of sample (two views)
- Infrared thermal imaging of sample (two views)
- Optical pyrometer measurements of sample (two channels)
- Reference temperatures for data analysis
- Downlink and uplink capability

Facility Integration

The ALF will be designed to be integrated in Spacelab and will interface with standard Spacelab power, thermal control, vent services, data, and computer.

- Special Interface Requirements: The ALF will interface with the Spacelab computer.
- Integration Options: None

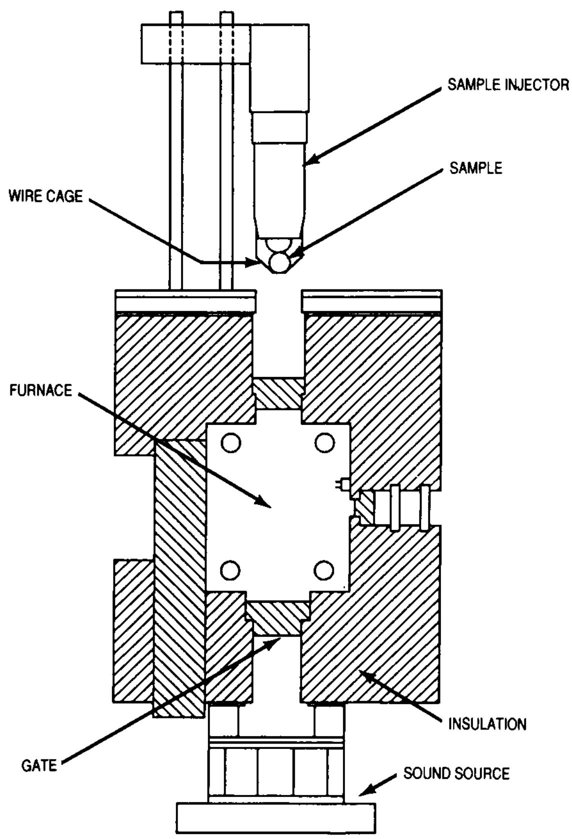
Additional Notes

Preliminary design and development of the ALF are in progress.

Development Center

NASA/Marshall Space Flight Center
Experiment Payloads Projects/JA51
Marshall Space Flight Center, AL 35812
(205) 544-1966

Single Axis Acoustic Levitator (SAAL)



Single Axis Acoustic Levitator

Importance

Containerless processing may make possible the preparation of ultrapure glasses used in optical and electrical applications. The chemical composition of some glasses requires processing at temperatures of 2,500 to 3,000 °C and greater; at these temperatures, no unreactive containers are available. On Earth, melts react with their containment crucibles causing impurities to form in the glass; in microgravity, containerless melting may eliminate this contamination. Additionally, acoustic processing at high temperatures on Earth is impossible because the sound waves cannot overcome gravity. The SAAL apparatus was the first space instrument to levitate, melt (at temperatures up to 1,500 °C), and resolidify glass samples acoustically. Experiments conducted in the SAAL have increased understanding of the role of nucleation in glass formation.

Method

Eight glass samples can be processed sequentially and automatically in the SAAL. Each sample is injected into the furnace cavity from a storage carousel attached to the hot-wall furnace. The sample is positioned without wall contact in the furnace cavity by acoustic energy nodes, which are formed when incident sound waves interfere with reflected sound waves in the furnace. During the melt phase, four silicon/carbide heating rods surround the levitated sample. After this phase, power is switched off the heating rods, allowing radiative cooling and solidification of the sample. Upon completion of the cooling phase, the solidified sample is retrieved by a retracting wire cage, and another sample is automatically inserted. A quartz window serves as a port for photographing the specimen during the experiment process.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

- Capacity/flight: 8 samples/flight
- Sample translation: Caged injector
- Spherical diameter: 4 to 10 mm

Physical Characteristics

- Furnace height: 93.50 cm
- Furnace diameter: 40.50 cm
- Furnace weight: 81.60 kg
- Injector cage: 2.50 cm x 2.50 cm x 2.85 cm
- Processing chamber: 10.20 cm x 10.20 cm x 11.40 cm

Operational Parameters

- Power: 3,100 W (peak); 2,600 W (average)
- Voltage: 32 ±4 Vdc
- Operating temperature: Up to 1,600 °C
- Pressure: 1 atm
- Atmosphere: Air or inert gas
- Levitator frequency: 15 kHz
- Cooling rate: 200 °C/min (sample dependent)

Instrumentation

- Pyrometer
- Thermocouples (2)
- Movie camera

Data Acquisition

Sample and furnace temperatures are recorded by the pyrometer and thermocouples, and a movie camera provides a photographic record of the processing during melts and solidifications. Data management is provided by the MSL Data Acquisition and Control system.

Facility Integration

The SAAL apparatus is housed in an Experiment Apparatus Container and is limited to use on the MSL carrier in the Shuttle orbiter payload bay.

- Special Interface Requirements: The SAAL requires electrical power, data management, cooling fluid, and air pressurant interfaces.
- Integration Options: None

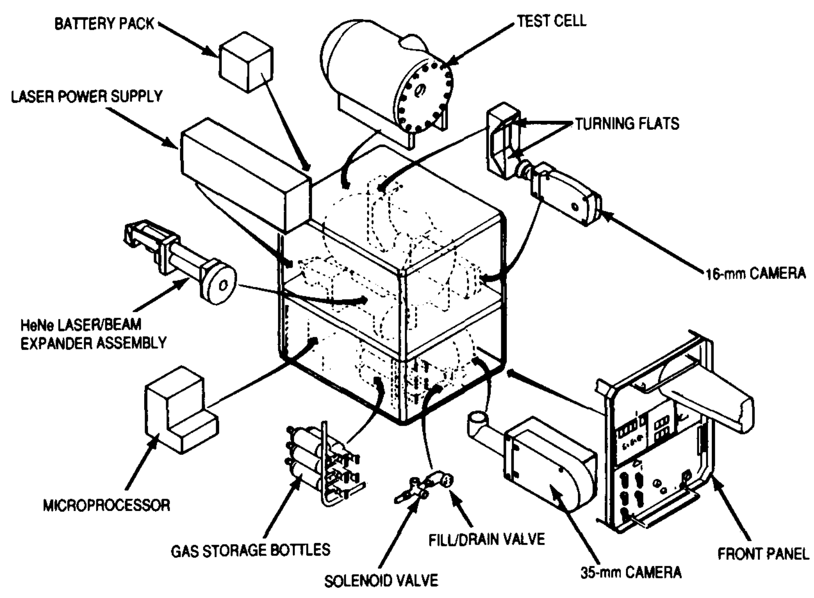
Additional Notes

The SAAL flew on the Materials Experiment Assembly (MEA-A1) as part of the OSTA-2 payload/STS-7, June 1983, and on MEA-A2 as part of the Spacelab D-1 mission, October 1985.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
(205) 544-1979

Drop Combustion Experiment (DCE) Apparatus



Drop Combustion Experiment Apparatus

Importance

Experiments conducted in the DCE apparatus will study drop behavior during combustion by measuring burning rates, extinction phenomena, disruptive burning, and soot production in burns that are spherically symmetric and will also investigate burns of non-spherical droplets by allowing an increase in drop velocity. A better understanding of the subtle processes occurring during combustion, including phenomena which influence burning rates and extinction conditions, could lead to improvements in the efficiency of combustion devices such as car engines and power plant furnaces. The DCE also may be used for combustion experiments involving small samples of other materials, such as paper and plastics.

Method

Experiments are conducted in a cylindrical test chamber that contains a fuel accumulator system, a droplet deployment system, a droplet igniter system, a pressure transducer, and two temperature transducers. In the DCE device, a fuel droplet, 1 mm in diameter, is formed at the end of two fine, syringe-like needles, which are slowly retracted so that the ends of the needles lie near the droplet surface. The needles are then quickly extracted from the droplet. After oscillations caused by the retractions have stopped, the drop is ignited by two simultaneous sparks on either side; this method of ignition is designed to minimize disturbance. Pressure and temperature sensors monitor the DCE test cell environment, and a film system photographs two perpendicular views of the burning droplet. One view focuses on the shrinking droplet surface to record changing diameter, the other on the flame diameter surrounding the droplet. As many as 25 consecutive tests can be conducted, each lasting about 12 minutes; droplet burning itself lasts less than 0.5 minutes for each test.

Carrier

Orbiter middeck

Sample Summary

• Stored liquid fuel volume:	Less than 0.6 cm^3
• Droplet size:	0.8 to 2.5 mm
• Droplet drift:	Less than 10 droplet diameters during droplet burn

Physical Characteristics

- Dimensions (LxWxH): 51.61 cm x 53.72 cm x 40.04 cm
- Weight: 54 kg
- Test cell volume: 12,000 cm^3

Operational Parameters

- Maximum power: 75 W from orbiter; 522 W from experiment battery pack
- Voltage: 28 Vdc
- Operating temperature: Within 5 °C of orbiter ambient temperature
- Operating pressure: 0.5 to 2 atm
- Maximum pressure rise: Less than 10% of operating pressure
- Test chamber environment: 10% to 50% O_2 and a dry, inert gas (N_2, Ar, He)
- Ignition: 110 mJ for 3 msec for each spark (two simultaneous sparks)

Instrumentation

Two-axis, high-speed (up to 200 frames/second) camera system records both 16- and 35-mm motion pictures.

Data Acquisition

Data are acquired solely by the camera system. Each film frame is tagged with chamber temperature and pressure and the time.

Facility Integration

The DCE apparatus is located in a double locker in the orbiter middeck.

- Special Interface Requirements: The DCE apparatus requires packing material to prevent vibration and a line to the Shuttle vent system. The device also has a 28-V electrical power hookup to the Shuttle.
- Integration Options: The apparatus is designed for a middeck double locker, but it may fit in the galley area or in Spacelab.

Additional Notes

An engineering model of the DCE hardware has been built and is being tested.

Development Center

NASA/Lewis Research Center
Space Experiments Division
21000 Brookpark Road
Cleveland, OH 44135
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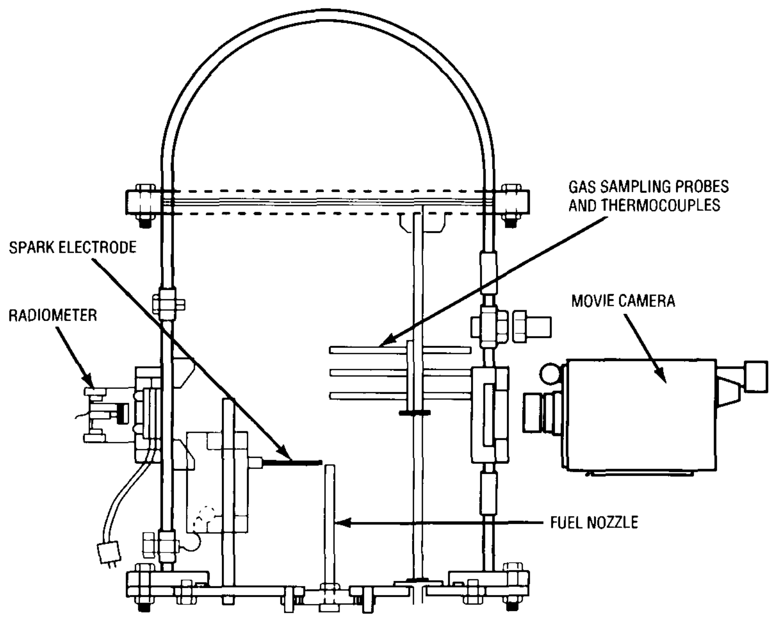
Gas Jet Diffusion Flames Apparatus (GDFA)



Gas Jet Diffusion Flames Apparatus (Conceptual Design)

Importance

The GDFA is being developed to investigate laminar gas jet diffusion flames, which are similar to candle flames, in a quiescent, well-defined, low-gravity environment. The apparatus will be used for environmental testing as part of a 3-year, ground-based research program, which may lead to a spaceflight experiment. Gas jet diffusion flames embody mechanisms operant in both unwanted fires and controlled combustion systems. Experiments conducted in the GDFA are designed to improve fundamental understanding of laminar gas jet diffusion flames by isolating the effects of buoyancy in a low-gravity environment. Results of these experiments may aid in the design of fire prevention techniques, both on Earth and in space. A better understanding of the simple laminar flame is a logical first step toward understanding the more complex turbulent diffusion flames that can be found in practical combustion systems, such as industrial burners.

Method

Using the GDFA, investigators will be able to study the effects of different nozzle sizes, gaseous fuel types, fuel flow rates, chamber pressures, and oxygen concentrations. Two versions of the GDFA are being designed. In both, a flame will be ignited in microgravity by a spark. A few seconds after ignition, sampling probes positioned above the flame will take gas samples of the combustion products. Continuous temperature measurements will also be made above the flame with an array of thermocouples. The heat emitted by the flame will be monitored with a radiometer, and the flame shape will be recorded with a high-speed movie camera.

Sample Summary

- Fuel: Methane or propane
- Fuel flow rate: 1 to 3 cm^3/sec

Physical Characteristics

- Chamber diameter: 40 cm
- Chamber height: 70 cm
- Nozzle inner radius: 0.051 cm or 0.083 cm

Operational Parameters

- Pressure: 0.5 or 1 atm
- Atmosphere: 15% or 21% O_2

Instrumentation

- High-speed movie camera
- Radiometer
- Thermocouple array
- Sample probe array
- Three-axis accelerometer system (KC-135 design)

Data Acquisition

Data will be acquired from 10 thermocouples, a pressure transducer, a radiometer, and 3 accelerometers at a rate of 20 readings/second. Gas samples from the 9 sampling probes will be analyzed to determine their chemical composition.

Facility Integration

Two versions of GDFA have been designed. One version will be configured within an experiment capsule for the 145-meter Zero-Gravity Research Facility at Lewis Research Center; the other design is for free-float testing in the Johnson Space Center KC-135 research aircraft.

- Special Interface Requirements: None
- Integration Options: None

Additional Notes

The GDFA is being built. Drop tower testing will begin in 1989, followed by aircraft testing. The results of this ground-based testing may lead to the development of a space experiment investigating gas jet diffusion flames.

Development Center

NASA/Lewis Research Center
Space Experiments Division
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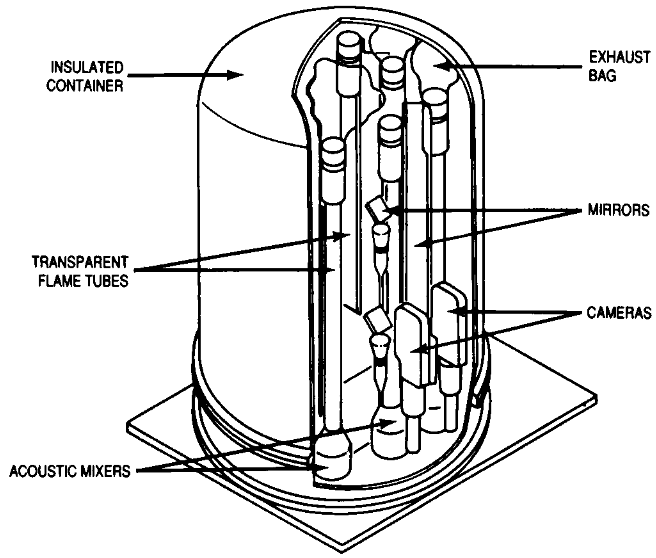
Particle Cloud Combustion Experiment (PCCE) Apparatus



Particle Cloud Combustion Experiment Apparatus

Importance

The PCCE apparatus allows investigators to study fundamental combustion processes, which are masked on Earth by buoyancy and gravitational settling. Flame properties for several two-phase combustion systems will be investigated. The uniform clouds of particulates that form in microgravity can be studied for flame propagation and extinction characteristics. (Particle clouds occur on Earth in coal mine and grain storage fires.) A better understanding of these basic combustion processes eventually may lead to more efficient use of fuels on Earth, reduce pollution resulting from combustion, and improve fire control and prevention technology.

Method

In the PCCE apparatus, eight separate quantities of fuel particles are mixed acoustically in transparent flame tubes to obtain quiescent, uniform clouds. When detectors have determined that an acceptable suspended particle density exists within a tube and after a quiescent period of 10 seconds, combustion is initiated automatically by an ignitor at one end of the flame tube. High-speed cameras record ignition, flame shape, propagation rate, and extinction. An exhaust heat exchanger and an expandable bag keep the flame tube pressure rise to within 0.2 psi/second. The sealed chamber pressure is controlled by chamber heat, and an indicator light notifies a crewmember when the next test may start.

Carrier

Materials Science Laboratory (MSL)

Sample Summary

- Capacity: 8 fuel-air ratios/flight
- Particle size: 25 to 55 micrometers

Physical Characteristics

- Sealed container
  - Inside diameter: 71 cm
  - Inside length: 129 cm
- Flame tube
  - Inside diameter: 5 cm ±0.2 cm
  - Inside length: 75 cm ±0.2 cm

Operational Parameters

• Power:	276 W
• Operating temperature:	Ambient ±6 K
• Operating pressure:	14.7 psia ±5%
• g-level (3 axis)	
- Set point:	5×10^{-4} g (or better)
- Stability:	$\pm 1 \times 10^{-4}$ g
• Air composition:	Dry air (21 ±1% O_2 ; 79% N_2)
• Particulate fuel	
- Set point precision:	±5%
- Mix uniformity:	±5% over tube length
- Concentration:	50 to 1,000 mg/1.5 liter

Instrumentation

- Two-branch fiber optics camera systems (4), allowing two views of each tube at 90 degrees
- Light-emitting diode particle detector system
- Pressure tranducers
- Thermocouples

Data Acquisition

Data for temperature, pressure, g-level, and concentration uniformity are acquired and stored in bubble memory, a data storage method in which data are very secure and easily retrievable. Photographic monitoring occurs at 100 frames/second.

Facility Integration

The PCCE is designed for integration on the MSL carrier in the orbiter payload bay.

- Special Interface Requirements: None
- Integration Options: None

Additional Notes

Seven flights are planned for the PCCE. The first flight will burn lycopodium; other flights will burn selected coals, cellulose, and mixtures of fuel and inert particles. The PCCE flight hardware is in the design stage.

Development Center

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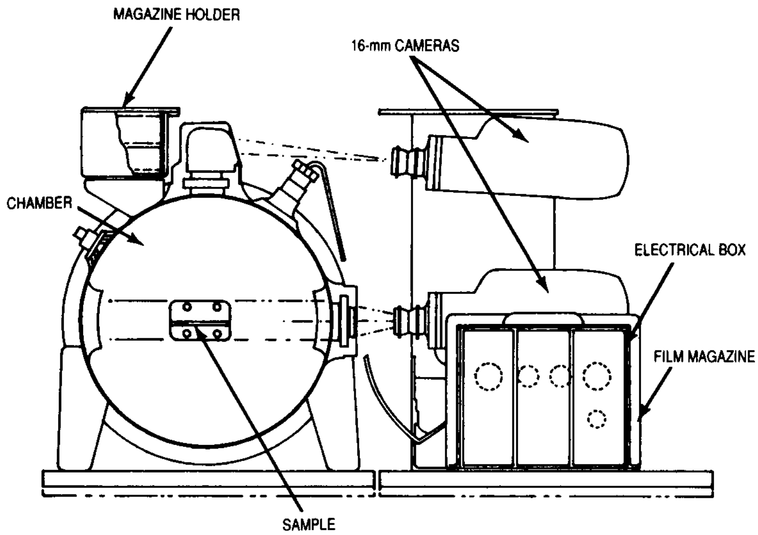
Solid Surface Combustion Experiment (SSCE) Apparatus



Solid Surface Combustion Experiment Apparatus

Importance

In microgravity, the absence of buoyant or forced gas-phase flow allows investigators to study other processes that influence the vapor phase of solid fuel combustion. The SSCE apparatus will investigate the mechanisms that control flame spreading on solid fuel surfaces. Information gathered through experimentation in the SSCE device will improve understanding of material flammability and burning characteristics.

Method

In the SSCE, thermally thin fuel samples, e.g., ashless filter paper, and thermally thick fuel samples, e.g., polymethylmethacrylate, are ignited and burned in a sealed chamber. Cameras in the adjacent SSCE instrumentation module photograph the burn from the face and side through two windows in the sample chamber. During a burn, measurements are made of the flame shape, the rate at which the flame spreads, chamber pressure, and the temperatures of the fuel surface and the gas phase.

Carrier

Orbiter middeck

Sample Summary

- Capacity/flight: 1 sample/chamber; up to 3 chambers/flight
- Dimensions
  - Thermally thin fuel: 0.018 cm x 3.0 cm x 10.0 cm
  - Thermally thick fuel: 0.315 cm x 0.630 cm x 2.0 cm
- Oxidizer environment (air): 30% and 50% O_2

Physical Characteristics

- Overall dimensions (LxWxH): 55.6 cm x 92.1 cm x 53.3 cm
- Electrical box dimensions (LxWxH): 26.0 cm x 20.3 cm x 21.9 cm
- Chamber dimensions (L x dia.): 51.3 cm x 34.3 cm
- Weight
  - Overall: 54 kg
  - Electrical box: 5.9 kg
  - Chamber: 14.8 kg
- Chamber volume: 0.039 m^3

Operational Parameters

- Power: 28 Vdc, 160 W (peak)
- Voltage: 28 Vdc
- Operating temperature: 16 to 32 °C

Instrumentation

- Thermocouples (3)
- Absolute pressure transducer
- Silicon temperature sensors (2)
- 16-mm motion picture cameras (2)

Data Acquisition

After 28-Vdc power is applied, an experiment start switch on the instrumentation module activates the control and data system. The system automatically sequences the start of the cameras, fuel ignition, thermocouple data recordings (1/sec and 20/sec), and pressure transducer data recording (1/sec). Data are recorded and stored for postflight evaluation.

Facility Integration

The SSCE sample chamber is designed to occupy the space of two modular stowage lockers; if three sample chambers are flown, six locker spaces are used. The *instrumentation module, containing the experiment* control system and data recording equipment, occupies two additional locker spaces.

- Special Interface Requirements: None
- Integration Options: The SSCE also can be located in Spacelab if a middeck locker-type interface is provided.

Additional Notes

The SSCE hardware is undergoing testing for flight qualification.

Development Center

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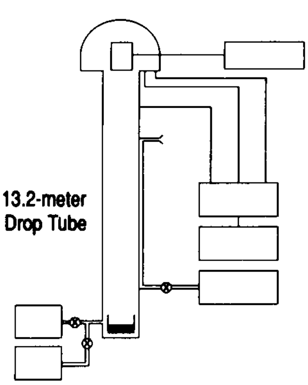
Ground-Based Research Facilities

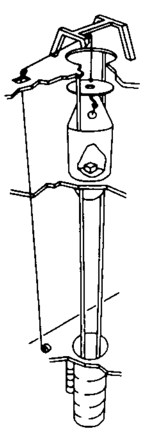
Microgravity science and applications research requirements have influenced the development of ground-based facilities that have a variety of experimental capabilities. Simulation facilities such as drop towers, drop tubes, and aircraft capable of parabolic flight contribute significantly to the advancement of microgravity science, even though their experiments last only a few seconds. Frequently, these studies are precursors to projects and programs that ultimately will use the Space Transportation System. In addition to simulation facilities, many other highly specialized ground-based facilities provide important opportunities for scientific advancement in the areas of crystal growth and levitation technology.



13.2-meter Drop Tube

Drop Tubes

Drop tubes accommodate small, uncontained material samples that are heated to the melt phase and allowed to resolidify under microgravity conditions during free fall in an evacuated tube. These free-fall periods last from 1.6 to 4.6 seconds, depending upon which drop tower is being used. Experimental requirements for rapid cooling rates are satisfied by backfilling the tube with inert gas before the drop run; however, the gaseous environment causes a small increase in aerodynamic drag, resulting in a slight reduction in the level of microgravity (10^{-6} g) that can be attained. One experimental facility, the 13.1-meter force-free drop tube, has been developed to overcome this drag. Three drop tubes are available for research studies: a 100-meter drop tube at NASA/Marshall Space Flight Center and a 13.1-meter force-free drop tube and a 13.2-meter cryogenic drop tube developed at the NASA/Jet Propulsion Laboratory (JPL).

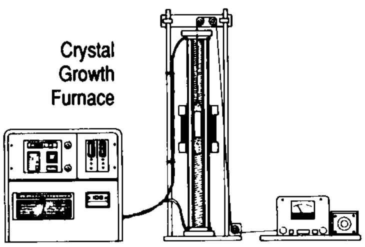


100-meter Drop Tower

Drop Towers

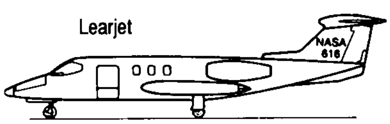
Drop towers accommodate large experiment packages, generally using a drop shield to contain the package and isolate the experiment from aerodynamic drag during free fall in the open environment. In the drop towers, free-fall periods range from 2.2 to 5.1 seconds. An auxiliary thrust may be provided to overcome the initial resistance of air friction, but some facilities use an evacuated drop chamber. Accelerations acting on the experiments are less than 10^{-5} g.

Three drop towers are currently available: a 145-meter zero-gravity research facility with a vacuum drop chamber, a 30-meter drop tower (both located at NASA/Lewis Research Center), and a 100-meter drop tower (NASA/Marshall Space Flight Center).



Dedicated Laboratories

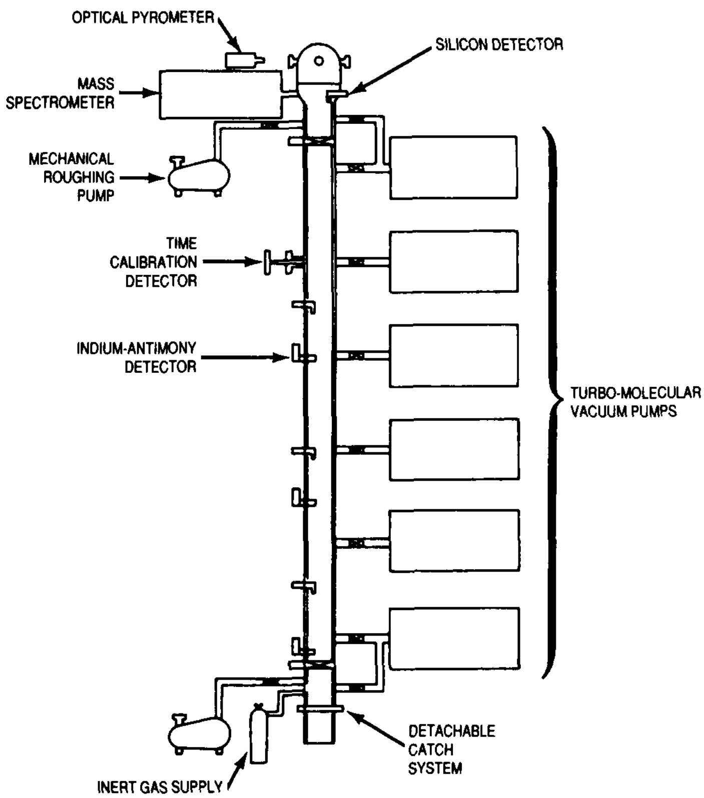
NASA has established several laboratories to support spaceflight experimentation. One of these facilities, the Microgravity Materials Science Laboratory, is available to scientists and engineers representing industry, academia, and Government interests. To assist researchers in experiment design, this laboratory is equipped with functional duplicates of experimental equipment flown on the Shuttle.



Microgravity Research Aircraft

The use of experimental aircraft flying parabolic trajectories provides a significant increase in processing time available for microgravity experimentation. Periods of 15 to 30 seconds of microgravity can be achieved during the central portion of the trajectory. During this free-fall period, gravitational effects in the range of 10^{-2} g can be obtained. In most cases, parabolic trajectories are repeated so that several periods of weightlessness are possible. In an aircraft, however, the variability of the reduced gravity makes precise experimentation difficult. Two aircraft currently perform frequent low-gravity flights: the KC-135 and the Learjet. The typical lead time for scheduling experiments varies between 1 and 6 months and is dependent upon the nature of the experiment and aircraft availability.

100-Meter Drop Tube



100-Meter Drop Tube

Importance

The 100-meter drop tube simulates in-flight microgravity conditions for up to 4.6 seconds and is used extensively for ground-based microgravity convection research in which extremely small samples are studied. Experiment results suggest that immiscible materials processed in space could form an entirely new class of electronic material. The facility can provide deep undercooling for containerless processing experiments that require materials to remain in a liquid phase when cooled below the normal solidification temperature; this may result in the production of unique alloys.

Method

The 100-meter drop tube has two apparatus for melting samples in the range of 500 to 3500 °C: the electron bombardment furnace and the electromagnetic levitator furnace. Experimenters also can choose to provide their own melting devices.

The melting apparatus is housed in a stainless-steel bell jar located directly above a stainless-steel drop tube. After the sample melts, it drops freely through the tube; the melting device does not fall with the sample. Samples decelerate as they are caught in a detachable fixture at the end of the fall.

The drop tube can be evacuated to a pressure of 10^{-6} Torr by six turbomolecular pumps located equidistantly along the tube. Under vacuum conditions, accelerations as low as 10^{-6} g are possible for as long as 4.6 seconds.

When samples are being inserted or retrieved, the furnace and catch tank can be sealed off from the rest of the tube to avoid filling the tube with air.

Sample Summary

- Diameter: Up to 5 mm
- Mass: Up to 300 mg
- Shape: Symmetrical with good aspect ratio

Physical Characteristics

- Tube diameter: 25.4 cm
- Tube length: 104.0 m

Operational Parameters

- Tube vacuum: 1×10^{-6} Torr
- Microgravity duration: Up to 4.6 sec
- Electron bombardment furnace
  - Temperature range: 1,600 to 3,500 °C
  - Pressure: Vacuum environment
  - Sample shape: Wire, rod, or disc
  - Data recorded: Thermal history, emission current striking sample
- Electromagnetic levitator furnace
  - Temperature range: 500 to 3,000 °C
  - Vacuum and low-pressure gaseous environments
  - Sample weight: Up to 0.25 g
  - Data recorded: Thermal history

Instrumentation

- Turbomolecular pumps (6)
- Roughing pumps (3)
- Infrared detectors (14)
- Closed-circuit television
- Mass spectrometer
- Sample furnace

Data Acquisition

The time of nucleation and thermal history are acquired through infrared detectors and pyrometers. The closed-circuit television records drop ejection and formation, and the mass spectrometer analyzes the gas content of the tube and records the sample cooling rate.

Development Center

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Microgravity Projects/JA61
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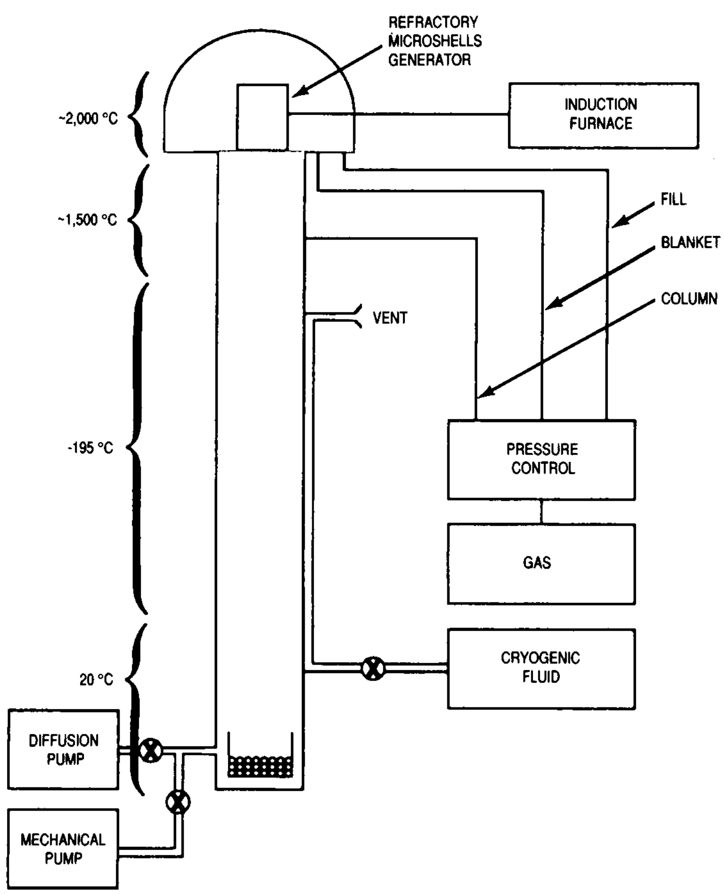
13.2-Meter Cryogenic Drop Tube



13.2-Meter Cryogenic Drop Tube

Importance

The 13.2-meter cryogenic drop tube provides a very low-temperature, controlled gas environment for the development of spherical shell technology, fusion target investigations, and the processing of metallic glass and metal alloys. Improvements in spherical shell technology may lead to the production of high-strength, lightweight materials. For example, aluminum shells in a close-packed hexagonal arrangement within an aluminum skin, when fused by sintering techniques, form a lightweight structural material of considerable strength. Spherical shells may also be used for the encapsulation of hazardous materials, as fire-retardant materials or recyclable filter materials, in heat-transporting slurries and shock-absorbing armor plate, and as insulation material.

Method

The sample to be processed in the 13.2-meter cryogenic drop tube is melted in a crucible that also injects the molten material with gas bubbles. The sample begins its 1.7-second free fall through the three temperature zones of the tube as a hollow stream, a cylinder of molten material surrounding a gaseous center. In the first zone of the tube, the sample is cooled to slightly below its melting/liquidus temperature, allowing the stream to pinch off into symmetrical droplets that surround gas bubbles. Each droplet then enters the cryogenic zone where the molten material cools around the gas bubble, forming a spherical shell. This second zone is chilled by a 10.66-meter liquid nitrogen (LN_2) cooling jacket that chills to LN_2 temperature in approximately 2 hours. The third zone is maintained at room temperature.

Sample Summary

• Size of shells produced:	100 microns to 3 mm
• Materials:	Aluminum, plastics, metal alloys, special glasses
• Crucible size:	500 ml to 1,000 ml

Physical Characteristics

• Tube diameter:	12.7 cm
• Tube length:	13.2 m
• Tube construction:	Thin-wall stainless steel

Operational Parameters

• Internal gas pressure range:	1 x 10^{-5} Torr to 1 atmosphere
• Microgravity duration:	1.7 sec
• Temperature	
- Crucible:	Up to 2,000 °C
- First zone:	Approximately 450 °C
- Second zone:	Down to -195 °C
- Third zone:	Ambient room temperature

Instrumentation

- Diffusion pump
- Mechanical pump
- Television (2) and monitors (2)
- Regulators
- Pressure relief valve
- Burst diaphragm

Data Acquisition

The sample can be observed through windows located directly below the sample drop generator and in the third temperature zone. Temperature and pressure data are acquired by thermocouples. Meters record the blanket pressures, flow rates, and gas supply to the crucible.

Development Center

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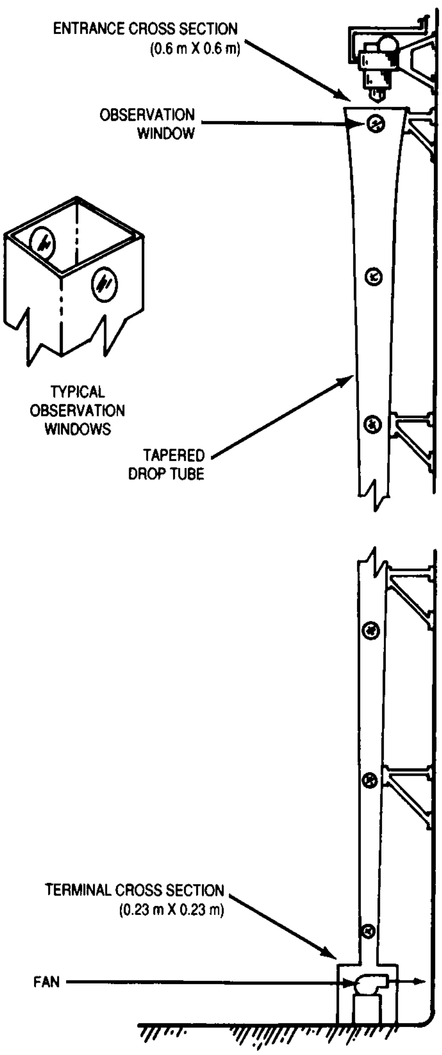
13.1-Meter Force-Free Drop Tube



13.1-Meter Force-Free Drop Tube

Importance

The 13.1-meter force-free drop tube is used in fluid surface configuration research. The facility provides investigators with a microgravity environment lasting up to 1.6 seconds, but unlike other drop tubes, this one is free of aerodynamic drag. Gravity and air drag distort the subtle characteristics of fluids; under microgravity conditions, these features may be more readily observed. A fundamental understanding of fluid dynamics is important for all space- and ground-based processing.

Method

A suction fan mounted at the base of this drop tube forces air downward at a constant acceleration of 1 g, creating an environment in which air velocity matches that of a freely falling fluid sample and eliminating sample distortion caused by air drag. Tapering of the drop tube increases the velocity of the air as it moves downward, and the design of the tube contour includes a correction for the displacement thickness of the turbulent boundary layer of the tube's interior walls. Several experiments can be conducted daily.

Sample Summary

- Size: Up to 5 cm in diameter

Physical Characteristics

- Tube diameter: 12.7 cm
- Tube length: 13.1 m
- View port diameter: 5.0 cm

Operational Parameters

- Temperature: Ambient room
- Microgravity duration: Up to 1.6 sec
- Acceleration level: 1 milli-g or greater

Instrumentation

Instrumentation is available but is installed only at an investigator's request. Pressure, temperature, and velocity may be measured, and the experiment may be photographed.

Data Acquisition

Data are acquired optically through five view ports. Pressure taps in the tube may be metered, and hot-wire anemometry capabilities are readily available.

Development Center

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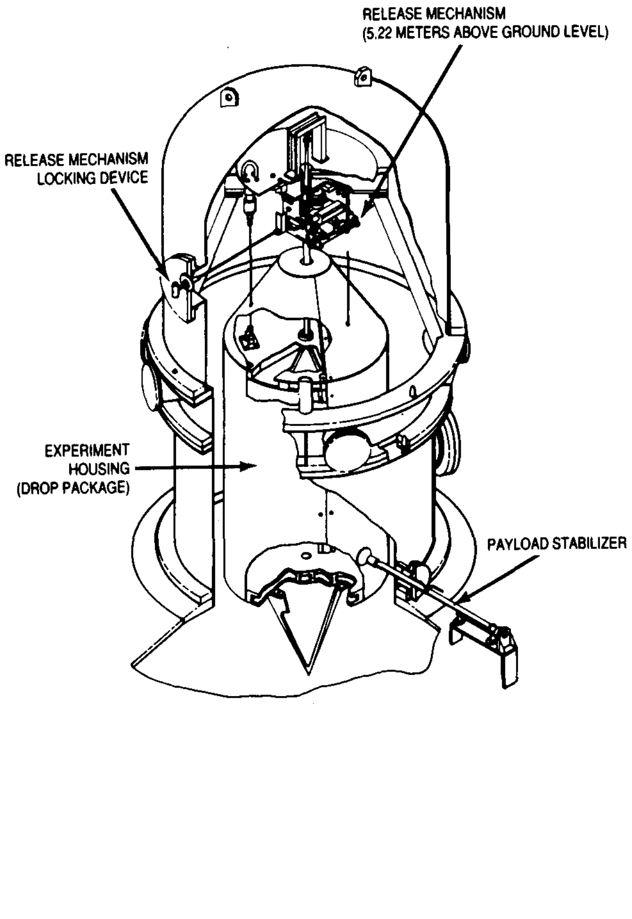
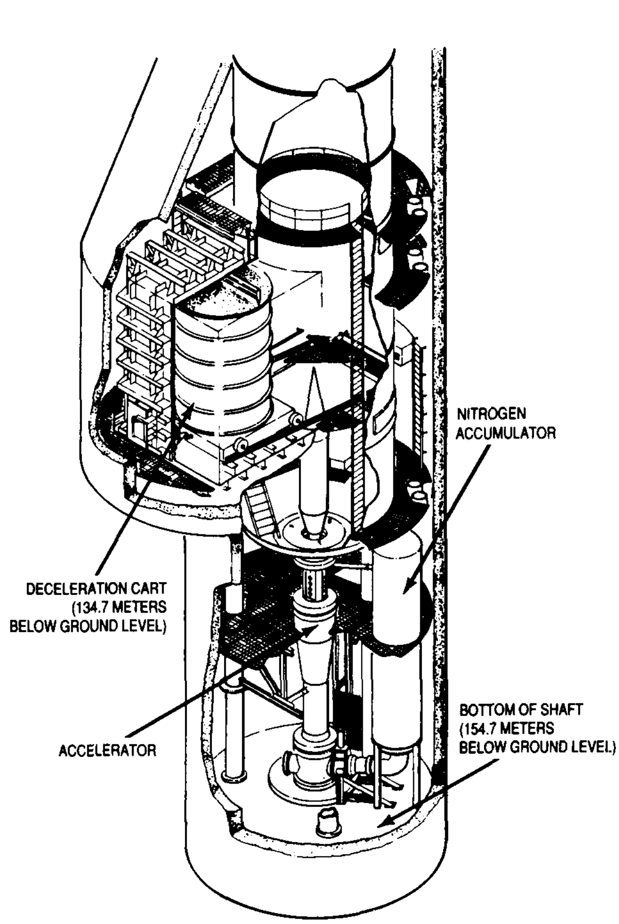
145-Meter Zero-Gravity Research Facility



145-Meter Zero-Gravity Research Facility (top)



145-Meter Zero-Gravity Research Facility (bottom)

Importance

The 145-meter Zero-Gravity Research Facility has been developed in support of microgravity research and development programs that investigate various physical sciences, materials, fluid physics, and combustion and processing systems. Large experimental packages can be operated and observed for periods of 5 seconds.

Method

In the Zero-Gravity Research Facility, a 145-meter shaft with an integral vacuum drop chamber, the experiment vehicle free falls from the top of the vacuum chamber, resulting nominally in 5 seconds of free fall. The experiment vehicle is suspended by its support shaft from a hinged-plate release mechanism in the top of the vacuum chamber. During chamber pumpdown and before release, the experiment vehicle system is monitored through an umbilical cable attached to the top of the support shaft, and electrical power is supplied from ground equipment. The system is switched to internal power a few minutes before release; the umbilical cable is detached from the support shaft 0.5 seconds before the drop; and the experiment vehicle is released as a bolt holding the hinged plate in the closed position is sheared pneumatically. This release procedure imparts no measurable disturbances to the experiment.

During the drop, the vehicle's trajectory and deceleration are monitored on closed-circuit television located in the control room. After the drop, the vacuum chamber is vented to the atmosphere, and the experiment vehicle is returned to ground level.

Sample Summary

- Cylindrical vehicle
  - Diameter: 1 m
  - Height: 3.4 m
  - Cold gas thrust system: 0.003 g to 0.015 g
  - Experiment payload weight: Up to 453.6 kg
  - Total system weight: 1,135 kg
- Rectangular vehicle
  - Dimensions (LxWxH): 1.5 m x 0.5 m x 1.5 m
  - Test specimen envelope (LxWxH): 0.61 m x 0.40 m x 0.45 m
  - Cold gas thrust system: 0.003 g to 0.037 g (positive); 0.013 g to 0.070 g (negative)
  - Experiment payload weight: Up to 69 kg
  - Total vehicle weight: 340 kg

Physical Characteristics

- Vacuum test chamber
  - Diameter: 6.1 m
  - Depth: 143.0 m
  - Drop height: 132.0 m
- Deceleration tank
  - Diameter: 3.3 m
  - Depth: 6.1 m

Operational Parameters

- Vacuum test chamber
  - Drop height: 132 m
  - Ultimate vacuum: 10^{-2} Torr (in 1 hour)
  - Aerodynamic drag: Less than 10^{-5} g
- Microgravity duration: 5.18 sec
- Deceleration rate
  - Mean: 35 g
  - Maximum range: 60 g for 20 millisec

Instrumentation

- Vacuum pumping system (4 stages)
- Supersonic Wind Tunnel Exhausters (2)
- Closed-circuit television
- Telemetry system
- Digital data system

Data Acquisition

- 18 channels of continuous data telemetered from experiment capsule (standard IRIG FM/FM)
- Frequency range: 6 to 10,000 cps
- Overall system accuracy: 2% to 3%
- High-speed motion picture data: 500 frames/sec; 1,000 quartz iodine lamps for lighting
- Onboard data computer system

Additional Notes

One or two tests per day can be conducted in the 145-meter Zero-Gravity Research Facility, depending on experiment complexity.

Development Center

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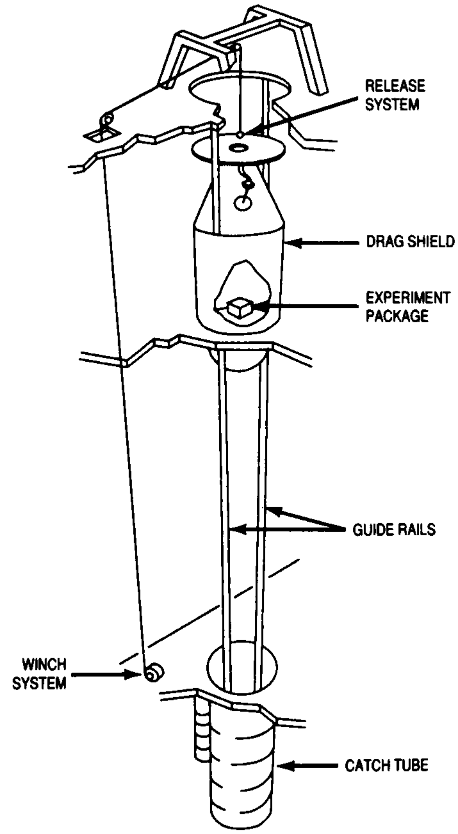
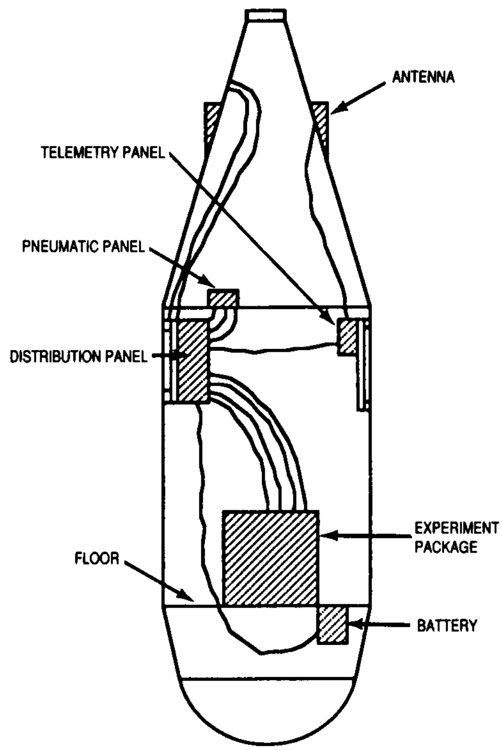
100-Meter Drop Tower



100-Meter Drop Tower



100-Meter Drop Tower Drag Shield

Importance

The 100-meter drop tower simulates in-flight microgravity conditions for up to 4.2 seconds for containerless processing experiments, immiscible fluids and materials research, preflight hardware design tests, and flight experiment simulation. Drop tube experimentation allows investigators to refine experiments and hardware and take full advantage of flight opportunities.

Method

The 100-meter drop tower is designed to accommodate large experiment packages, which are provided by the investigator and contain all instrumentation required for sample melting and internal data collection. These packages are housed in a shield to isolate the experiment from aerodynamic drag during free fall. To overcome the decelerating forces of air resistance and friction from the two guiderails on which the drag shield rides to the bottom of the tower, the drag shield is given a downward thrust by gas thrusters; this allows a properly balanced experiment package to float inside the drag shield. During a drop, g-levels between 4×10^{-2} g and 10^{-5} g can be attained. At the end of its fall, the drag shield is decelerated at 25 g as it compresses air inside a tube and then settles on a cushion at the bottom. Up to 10 drop runs a day can be conducted, depending on the furnace and material used.

Sample Summary

• Height:	0.9 m
• Width:	0.9 m
• Length:	0.9 m
• Weight:	180 kg (maximum)
• Capacity:	0.73 m^3 (maximum)

Physical Characteristics

• Drop tower	
- Total drop height:	101.7 m
- Free-fall height:	89.5 m
• Drag shield	
- Length:	7.4 m
- Diameter:	2.2 m
- Test area:	1.8 m x 2.4 m
- Weight:	1,642 kg

Operational Parameters

• Drag shield free-fall duration:	4.275 sec
• Drag shield deceleration:	25 g
• Auxiliary thrust:	34 kg
• Low-gravity range:	1×10^{-5} to 4×10^{-2} g

Instrumentation

• Power and compressed air distribution panels:	238 bar, 3,500 psig
• Charge-coupled device camera:	30 frames/sec
• Auxiliary thrusters	

Data Acquisition

Test data are transmitted by telemetry to a ground station for processing. A low-gravity accelerometer can be placed in the package to measure g-levels. A 35-mm film camera for making high-speed movies can also be placed in the package; this camera is to be replaced by a videotape recorder.

Development Center

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Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
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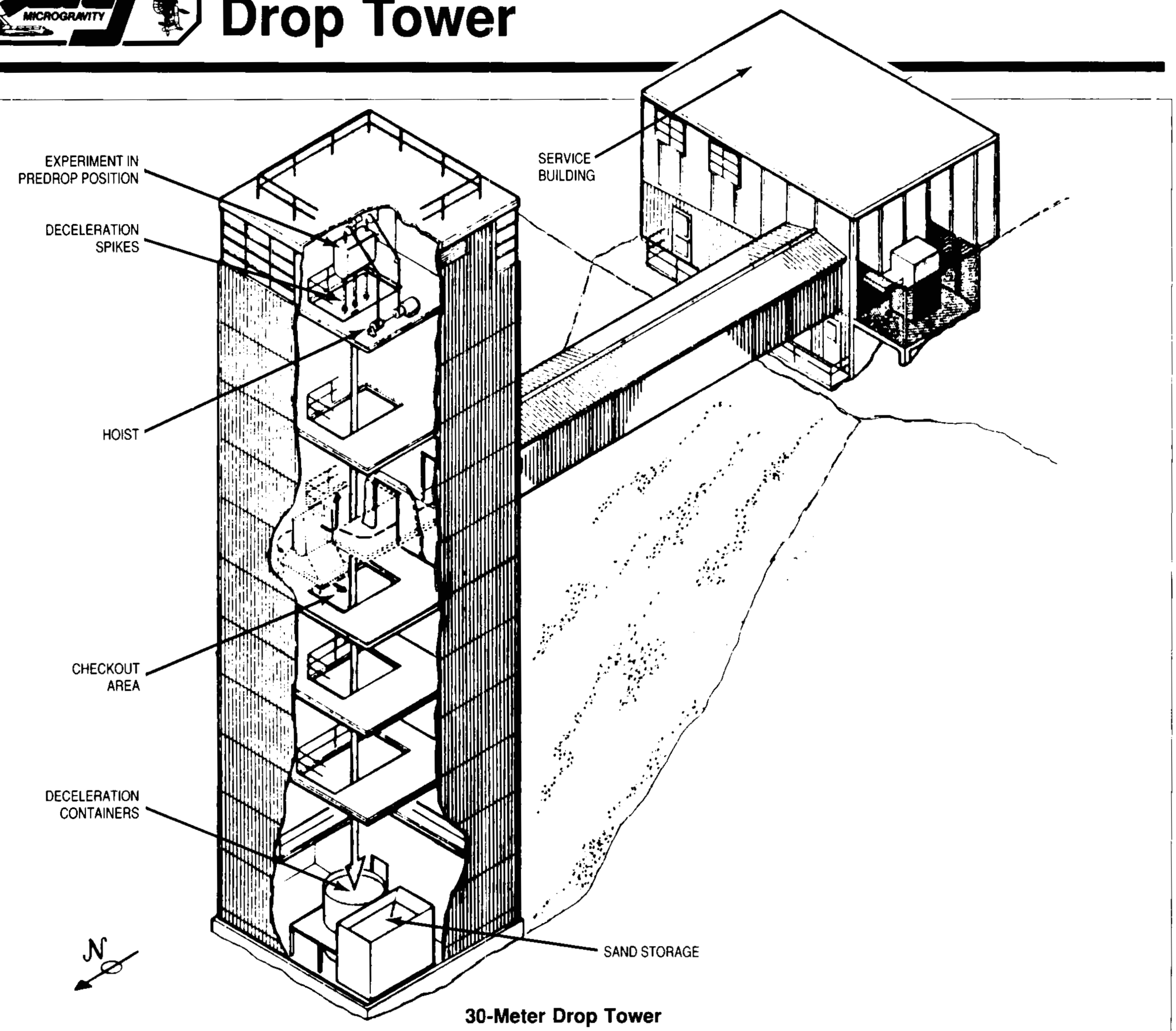
30-Meter Drop Tower



30-Meter Drop Tower

Importance

The 30-meter drop tower allows investigators to test experiment packages in a microgravity environment for a period of 2.2 seconds. Up to 12 drop tests a day support ground-based combustion science and fluid physics programs, precursor tests that define space experiment science requirements and conceptual designs, and tests for space experiment technology development and verification. This facility is operated at a relatively low cost, and engineers participate directly in experiment buildup and testing.

Method

In the 30-meter drop tower, experiment packages are enclosed in a drag shield that has a high ratio of weight to frontal area and a low drag coefficient. The drag shield/experiment assembly is hoisted to the top of the building where it is suspended by a highly stressed wire. A drop begins as the wire is notched, causing it to fail. In this way, the drag shield assembly is released smoothly, and no measurable disturbances are imparted to the experiment. During the 27-meter fall, the experiment package falls freely a distance of 20 centimeters within the drag shield, and the only external force acting on the experiment is the air drag associated with the relative motion of the package within the enclosure of the drag shield. The drag shield is decelerated in a 2.2-meter deep sand pit. Onboard power is provided during the drop by battery packs.

Sample Summary

- Rectangular drop rigs (2)
  - Width: 41 cm
  - Length: 96 cm
  - Height: 65 and 84 cm
- Experiment hardware weight: Up to 100 kg

Physical Characteristics

- Drop height: 27 m
- Drag shield dimensions (LxWxH): 102 cm x 51 cm x 137 cm

Operational Parameters

- Microgravity duration: Up to 2.2 sec (free fall)
- Gravitational acceleration: Less than 10^{-5} g
- Deceleration rate: Up to 60 to 70 g
- Deceleration distance: 2 m
- Deceleration time: 0.75 sec

Instrumentation

- Movie cameras
- Battery packs
- Thermocouples
- Pressure transducers
- Flow meters
- Lasers

Data Acquisition

Data are acquired by an onboard data acquisition and control system. High-speed movie cameras record the experiment sequence in real time.

Development Center

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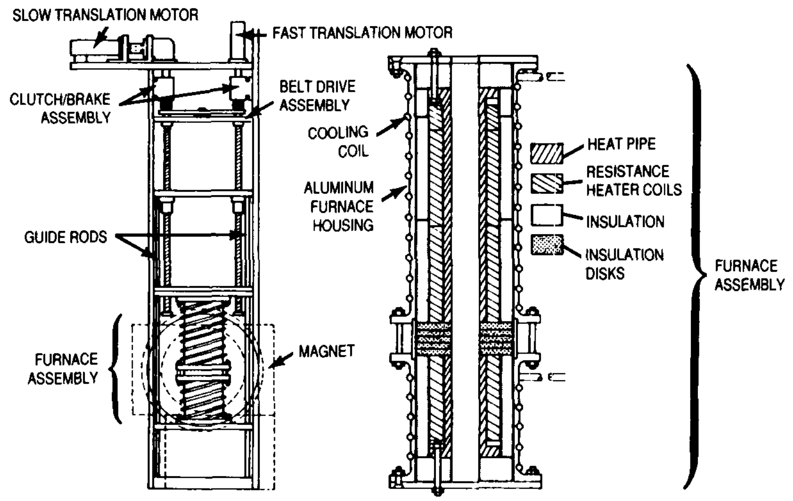
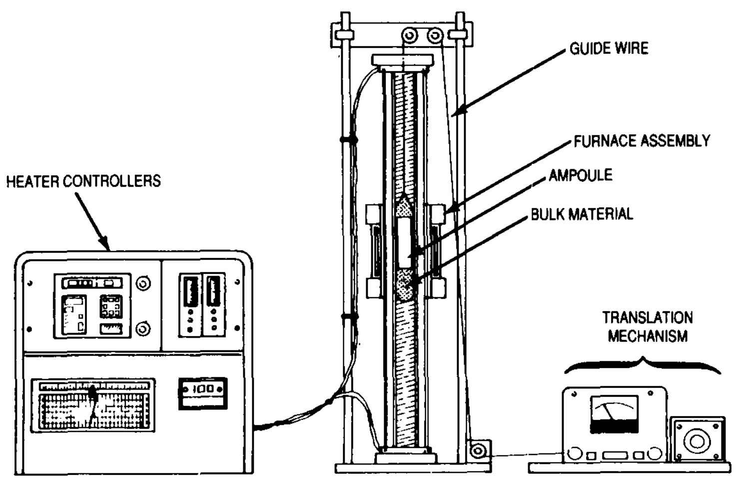
Microgravity Materials Science Laboratory (MMSL)



High-Temperature Directional Solidification Furnace



Crystal Growth Furnace

Importance

The MMSL, located at Lewis Research Center (LeRC), is a facility in which an investigator can explore concepts in microgravity science and examine ideas aimed at potential flight experiments before a formal research effort is established. The laboratory provides industrial, academic, and Government researchers access to and assistance with experiment equipment that is functionally similar to Shuttle flight hardware. The MMSL also can be used to develop an understanding of a materials or processing phenomenon in a 1-g environment. It is fully equipped with appropriate materials research facilities and is supported by the extensive LeRC materials, characterization, and computational capabilities.

When it first began operations, the MMSL provided support primarily to researchers investigating metals and alloys; currently, however, the laboratory facilities are being expanded to include a ceramics and glass laboratory and a polymers laboratory. With the addition of these new facilities, the MMSL will be able to support most areas of research in microgravity materials science.

Method

Investigators interested in using the MMSL must submit a brief proposal describing the experiment, and their proposed research must be related to microgravity materials science topics. Although the work conducted in the MMSL is performed in Earth gravity (1-g), an experimenter must demonstrate the intent to conduct follow-on experimentation in a microgravity environment, using ground-based microgravity facilities or applying to NASA to fly the experiment aboard the Shuttle. The purpose of the proposal is to demonstrate the technical merit of the experiment and its relationship to microgravity materials science. The proposal must also indicate what MMSL capabilities are required at each stage of experimentation.

Scientists and engineers directly associated with the MMSL and other members of the technical staff at LeRC form the committee to review and evaluate proposals. They consider the scientific merit of the proposed experiment, the availability of resources at the time of submittal, and the dates the visiting researcher desires to conduct the experiment. Proposals that can be accommodated with existing facilities and capabilities are more likely to be approved by the committee than those for which no support can be provided by the home organization.

Every experimental program that will be conducted by a visiting scientist or engineer in the MMSL requires a formalized agreement. Based on discussions with the MMSL manager and the LeRC technical staff, the agreement is developed and the formal Microgravity Materials Science Experimentation Agreement for Visiting Scientists and Engineers is drafted. Following a favorable review of the technical aspects of the proposed experiment, discussions begin between the LeRC staff and the visiting researcher and his/her home organization to negotiate the level of support that NASA will provide. The agreement also establishes the MMSL level of effort and number of staff assigned to support an experiment directly and the funds allocated to procure experiment materials, supplies, and equipment. LeRC intends to support the visiting researcher's experimentation to the fullest extent possible based on the resources available to the MMSL program. Concurrent commitments with other visiting scientists and engineers determine the level of resources that are available at any given time.

Apparatus Available

- General Purpose Furnace
- Electromagnetic Levitator
- Instrumented Drop Tube (1 sec)
- Undercooling Furnace
- Bulk Undercooling Furnace
- Transparent Directional Solidification Furnace
- High-Temperature Directional Solidification Furnace
- Isothermal Dendrite Growth Apparatus
- Crystal Growth Furnace
- Single Axis Acoustic Levitation Furnace
- Complete characterization facilities for ceramics and polymers, including thermal, surface area, and particle size analyses

Data Acquisition

- Dedicated instrument computers
- MMSL general purpose computers
- LeRC mainframe computers

Additional Notes

More information about the facilities, capabilities, and uses of this laboratory is available in the NASA/LeRC publication "Microgravity Materials Science Laboratory - Laboratory Description and Scientist and Engineer's Application Procedures for Its Use," 1987.

Development Center

NASA/Lewis Research Center
Microgravity Materials Science Laboratory
21000 Brookpark Road
Cleveland, OH 44135
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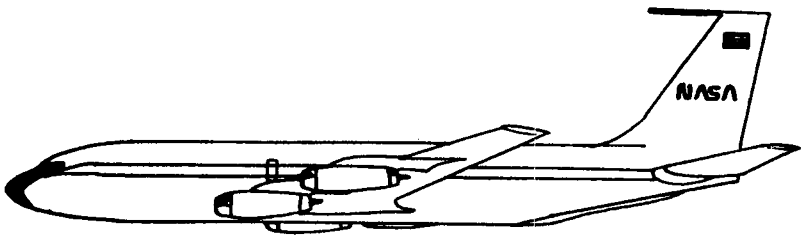
KC-135 Aircraft



KC-135 Aircraft

Importance

The KC-135 can simulate up to 40 periods of low-gravity for 25-second intervals during one flight. The aircraft accommodates a variety of experiments and is often used to refine spaceflight experiment equipment and techniques and to train crewmembers in experiment procedures, thus giving investigators and crewmembers valuable experience working in a weightless environment.

Method

The KC-135, like other microgravity research aircraft, obtains weightlessness by flying a parabolic trajectory. The plane climbs rapidly at a 45-degree angle (pull up), slows as it traces a parabola (pushover), and then descends at a 45-degree angle (pull out). The forces of acceleration and deceleration produce twice the normal gravity during the pull up and pull out legs of the flight, while the brief pushover at the top of the parabola produces less than 1 percent of the Earth's gravity.

The KC-135 flies its 40 parabolic trajectories between 7.32 and 10.37 km. Qualified observers or operators may fly with their experiment packages. The KC-135 is located at Johnson Space Center in Texas.

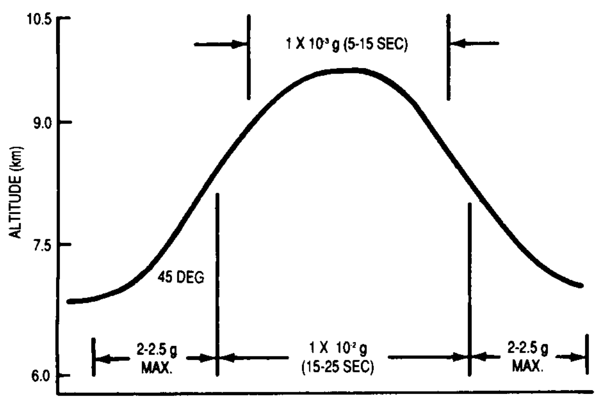
Experiment Summary

Experiment package size is limited by the following KC-135 accommodations:

- Bay dimensions: 3.04 m x 16.4 m
- Bay overhead clearance: 1.8 m
- Maximum floor loading: 90 kg per 0.09 m^2

Physical Characteristics

- Description: 4-engine, jet cargo-type aircraft
- Personnel: Varies, depending on mission requirements
- Trajectory altitude: 7.32 to 10.37 km
- Flight duration: 2 to 3 hours



KC-135 Flight Characteristics

Operational Parameters

- Acceleration: 2.5 g
- Power: 28 Vdc, 80 A; 110 Vac, 50 A, 400 Hz; 110 Vac, 25 A, 60 Hz
- Microgravity duration: 25 sec
- Number of maneuvers/flight: 40

Instrumentation

Experiment packages will contain all instrumentation that the experiment requires.

Data Acquisition

The KC-135 acquires only trajectory data. Any other data collection capabilities must be contained in the experiment package.

Facility Integration

Equipment must be self-contained and restrained upon takeoff and landing.

- Special Interface Requirements: Apparatus must meet Johnson Space Center safety requirements.
- Integration Options: Power is available from the KC-135.

Development Center

NASA/Marshall Space Flight Center
Microgravity Projects/JA61
Marshall Space Flight Center, AL 35812
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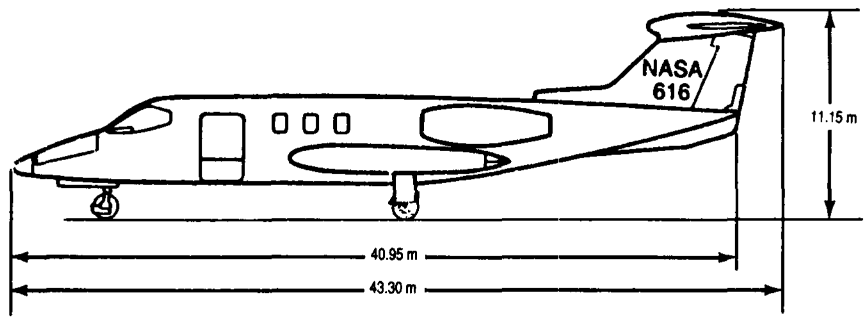
Learjet



Learjet Dimensions

Importance

The Lewis Research Center (LeRC) Learjet Model 25 aircraft provides investigators with a cost-effective way to conduct and observe experiments in simulated microgravity. The aircraft allows 15 to 20 seconds of experimentation in low gravity, significantly longer than the processing times attainable in drop towers and tubes. Flight-qualified investigators may conduct and monitor their experiments, or an investigator may request that a flight-qualified observer from the LeRC Space Experiments Office operate the experiment. To improve instrument performance, investigators may reconfigure experiments between the Learjet's flight trajectories.

Method

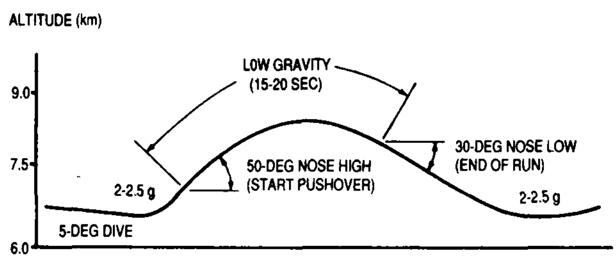
The Learjet, like other microgravity research aircraft, achieves weightlessness by flying a parabolic trajectory. The plane climbs rapidly at a 50- to 55-degree angle (pull up), slows as it traces a parabola (pushover), and then descends at a 30-degree angle (pull out). The brief pushover at the top of the parabola produces less than 1 percent of the Earth's gravity (10^{-2} g) for 15 to 20 seconds. If this flight trajectory is modified, the Learjet can attain intermediate acceleration levels ranging from 5×10^{-2} to 75×10^{-2} g. The Learjet can complete a maximum of six trajectories before landing, if conditions of minimum acceleration are attained; more trajectories are possible for flights at higher acceleration levels.

Physical Characteristics

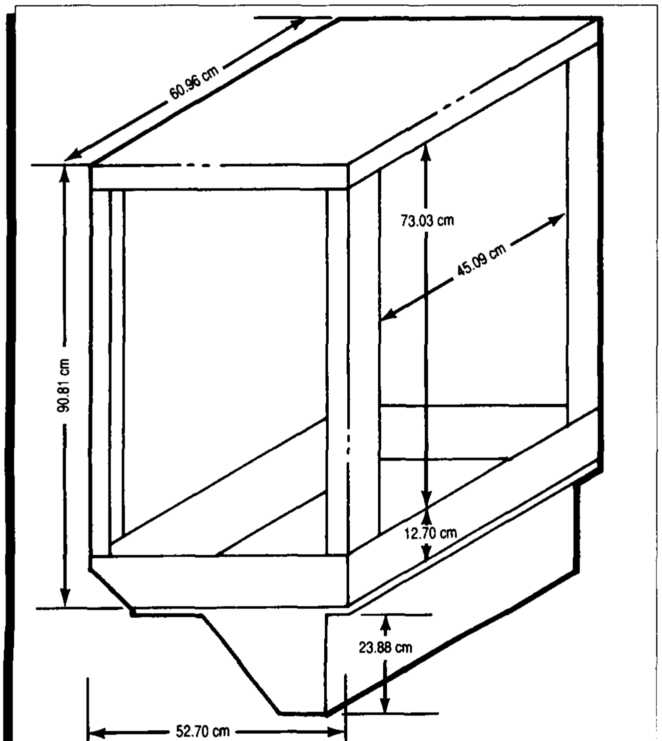
- Description: Model 25; small passenger jet
- Personnel: 2 crewmembers; up to 3 investigators/observers
- Trajectory altitude: 3.36 to 5.49 km

Operational Parameters

- Maximum power: 28 Vdc, 80 A; 110 Vac, 60 Hz, 8.6 A; 110 Vac, 400 Hz, 21.7 A
- Microgravity duration: 15 to 20 sec
- Acceleration: 10^{-2} g (approximate minimum)
- Number of maneuvers/flight: 6 (maximum at 10^{-2} g)



Learjet Typical Low-Gravity Trajectory



Learjet Instrument Rack

Instrumentation

- Three-axis accelerometer system
- LeRC-approved instrumentation provided by the investigator

Data Acquisition

Accelerometers and a recorder document each trajectory. The investigator also may record these data with a compatible instrument. Other data acquisition systems, approved by LeRC, may be used at the customer's option. Either customer- or LeRC-furnished equipment may be used to photograph the experiments.

Experiment Integration

Approximately 1.8 meters of cabin length are available for experiment mounting and observer seating. A rear bench can be used for seating or can be removed and its space used for hardware installation. Customer-furnished hardware must be approved through the LeRC safety review process. LeRC recommends that research apparatus be installed in LeRC-furnished instrument racks, two of which can be mounted in the Learjet. The rack characteristics are:

- Dimensions (LxWxH):
  60.96 cm x 52.70 cm x 90.81 cm
- Stress limits
  - Weight: 84.6 kg
  - Total moment: 369.46 Nm

Development Center

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